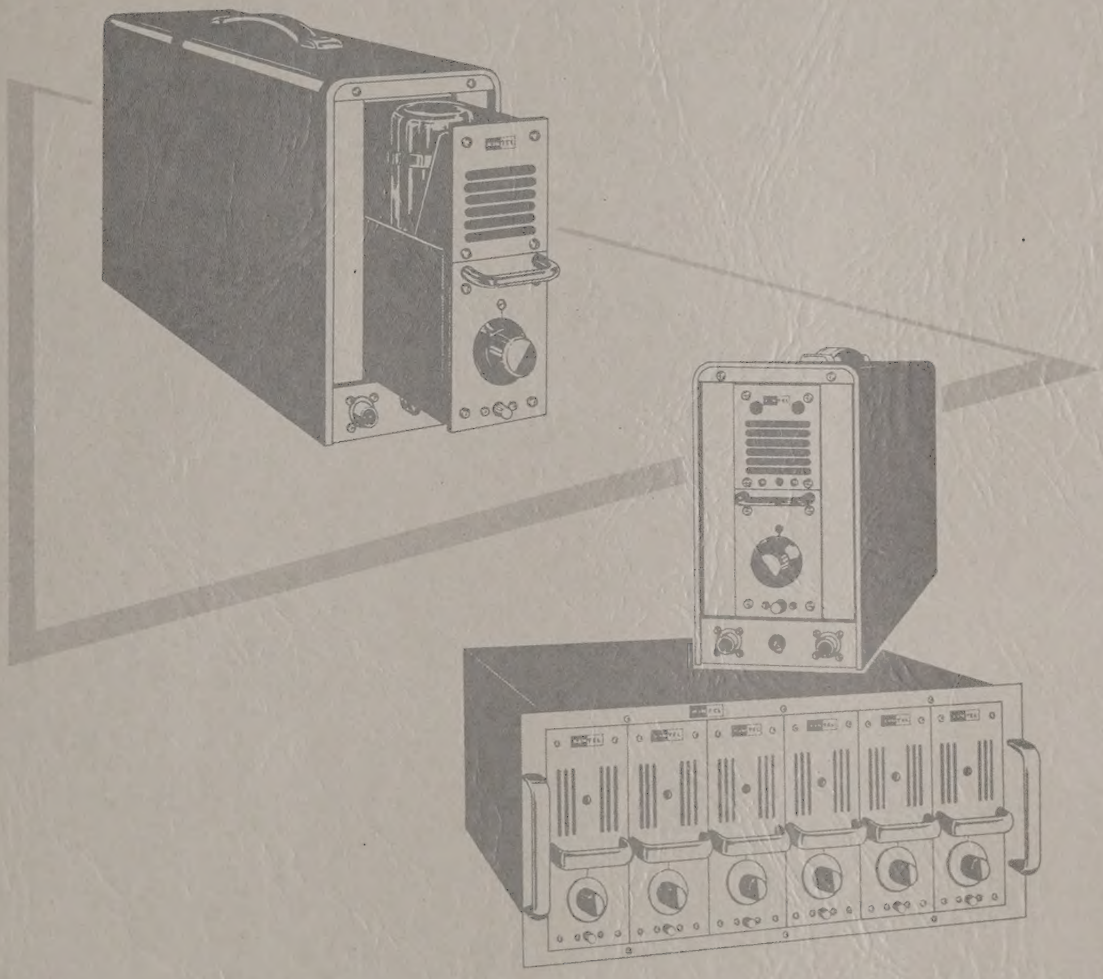

OPERATING AND MAINTENANCE INSTRUCTIONS FOR

MODEL 111 SERIES WIDEBAND

DC AMPLIFIER

5725 KEARNY VILLA ROAD • SAN DIEGO 11, CALIFORNIA • BR 7-6700

KINTEL
A DIVISION OF
COHU
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OPERATING AND MAINTENANCE INSTRUCTIONS FOR WIDEBAND DC AMPLIFIERS MODEL 111, 111A, 111AF, AND 111BF

KIN TEL, A Division of Cohu Electronics, Inc.
5725 Kearny Villa Road
Box 623
San Diego 12, California

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Section I
GENERAL DESCRIPTION

1-1 INTRODUCTION

1-2. The Model 111 series of DC Amplifiers are precision laboratory decade units designed to accept very small DC signals having transients up to several kilocycles and to provide low-impedance output signals for driving conventional metering instruments. The amplifier circuits are designed for ultra linear and highly stable amplification. Units are packaged compactly in modular form for mounting singly or in banks of six in specially designed cabinets. (See Figures 1-1 and 1-2.) The original Model 111 DC Amplifier design has been subjected to design refinements resulting in a highly versatile unit serving as the basic component in all types of data transmission.

Figure 1-2. Single Model 111BF Amplifier in Model 195 Cabinet

Figure 1-1. Six Model 111BF Amplifiers Installed in a Model 190 Cabinet for Rack Mounting

1-3 IDENTIFICATION

1-4. The original Model 111 Amplifier (Figure 1-3) was modified to incorporate circuit refinements, and the improved unit was designated Model 111A. Model 111AF Amplifiers provided the extra versatility of a floating ground which permitted operation with transducers strapped to ground at the pickup location. Further versatility was incorporated in another version, Model 111AFO which provided for disconnecting the internal negative feedback circuit, adding external resistive and reactive components for another feedback loop that provided specialized transmission characteristics.

1-5. The amplifier circuit was modified again to incorporate additional design refinements, including a vernier gain control. This unit was designated the Model 111BF since it retained the floating signal ground. The operational Model 111BFO Amplifier provides open-loop operation in the zero-gain position of the panel control.

1-6. These amplifiers are used conveniently in either of two specially designed cabinets that provide automatic electrical connections on a plug-in connector, input and output wiring to standard panel connectors, and a blower for cooling. The Model 195 Cabinet (Figure 1-2) accepts a single amplifier, and the Model 190 unit accommodates six amplifiers and is sized and drilled for mounting in a standard 19-inch rack.

NOTE

These cabinets also accept the Model 114 Amplifiers which are similar to the Model 111 units but isolate input and output grounds.

Figure 1-3. Model 111 Amplifier

Figure 1-4. Model 111BF Amplifier

1-7 PHYSICAL DETAILS

1-8. The Model 111 Amplifier (Figure 1-1) has a long narrow form and is built for installation in a cabinet as a drawer with plug-in connections at the rear. A front panel, 2-7/8 inches wide by 7-5/8 inches tall, provides fixed gains on an 11-position tap switch, a screwdriver balance control, indicator lamps to show AC power on and amplifier overload. The Model 111BF and Model 111BFO panels also have vernier gain controls. In addition, the panels have latches, ventilating slots in the upper part, and a handle to facilitate installing and removing. (See Figure 1-4.)

1-9. The amplifier is 15-5/8 inches long and requires space behind the panel of 14-3/8 inches. (See Figure 1-5.) The heavier components are mounted at the rear of the chassis to afford greater ease in inserting and withdrawing the units and to make them more stable when partly out of the cabinets. The right side of the chassis extends up to full height to act as an effective inter-unit shield in multi-amplifier installations. (See Figure 1-1.) A 12-contact connector for mating with matching connectors is at the rear of the mounting cabinets. (See Figure 1-6.) The amplifier weighs 11-1/2 pounds out of the cabinet.

1-10. The Model 195 Cabinet is a sturdy metal case designed to accept a single Model 111 (or Model 114) Amplifier. (See Figures 1-2 and 1-7.) It receives the amplifier as a drawer

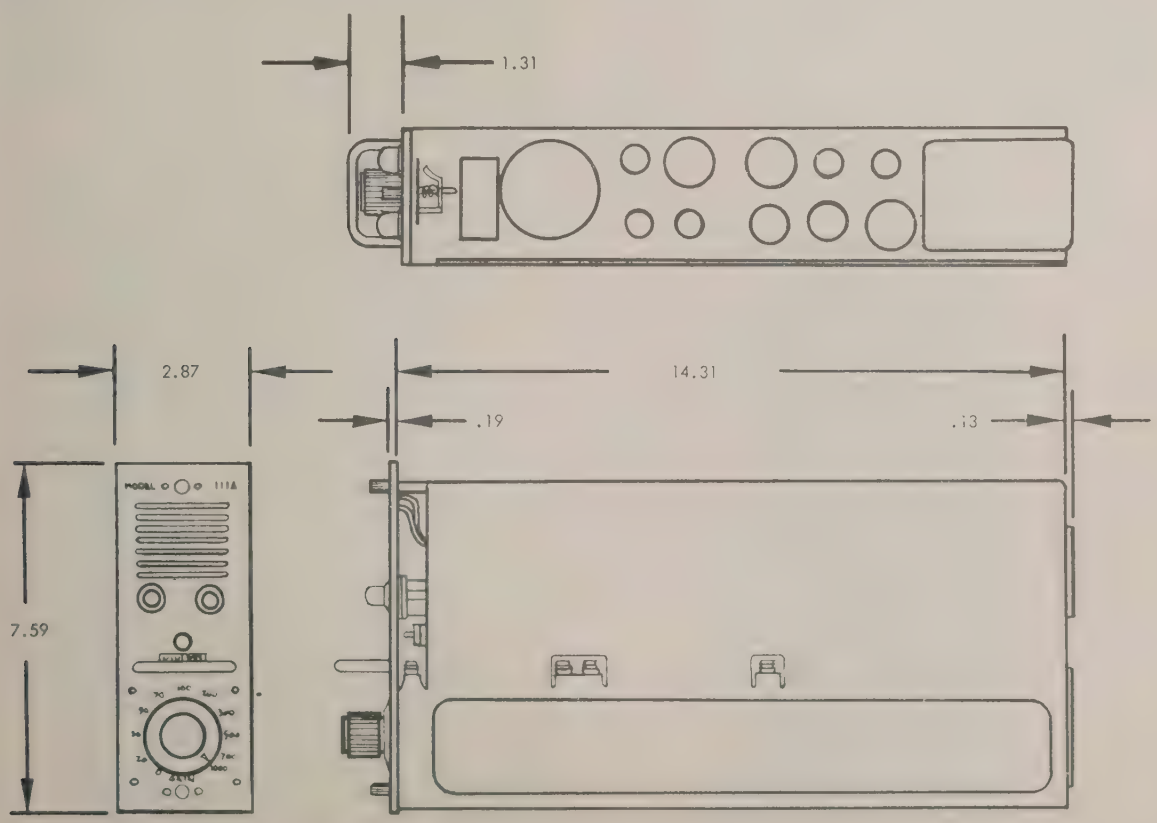


Figure 1-5. Outlines and Dimensions of Model 111 Series Amplifiers

and has a connector at the rear to match that on the amplifier (Figure 1-6.) This cabinet is equipped with input and output connectors and an ON-OFF switch on a small panel just below the amplifier space. An AC power cord at the rear brings in line voltage and a small electric blower is provided for cooling. It is 5-7/16 inches wide, 10 inches high, and 18-1/4 inches deep. It weighs 13 pounds without an amplifier installed.

1-11. The Model 190 Cabinet is a rack adaptor for using up to six Model 111 (or Model 114) Amplifiers. This unit is a square-cornered pan with handles to facilitate mounting in and removal from a standard 19-inch rack, and is equipped with facilities to accommodate the amplifiers -- connectors at the rear and three blowers for ventilation. (See Figure 1-1.) There are no ON-OFF switches or connectors at the front of this cabinet. Input and output connections are made via shielded cabling led through grommeted holes on the sides of the cabinet at the lower rear corners. This cabinet is 19 inches wide, 8-3/4 inches high, and 18-1/4 inches deep. (The width behind the front panel is 17-5/8 inches.) The cabinet weighs 34 pounds without any amplifiers installed.

1-12 ELECTRICAL CHARACTERISTICS

1-13. The Model 111 Amplifiers are extremely stable and drift-free DC units for wideband amplification of microvolt-level signals. Gains are precise and selectable by a tap switch on the front panel. Output impedance is very low. The Model 111BF units have vernier gain controls affording a continuous 1 to 2 times variation of each fixed gain so that overall amplification extends to 2000 (66 db). The operational amplifiers, Model 111BFO (also Model 111AFO) have the same

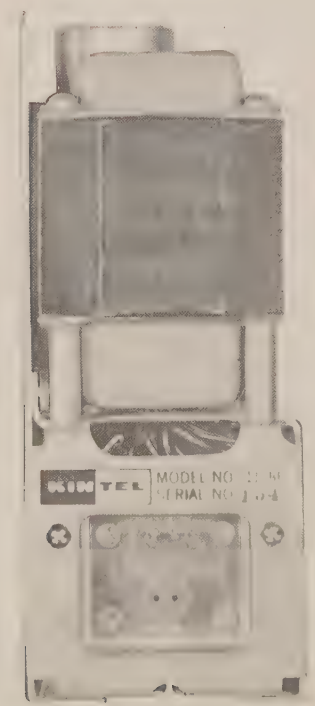


Figure 1-6. Rear of Model 111 Amplifier

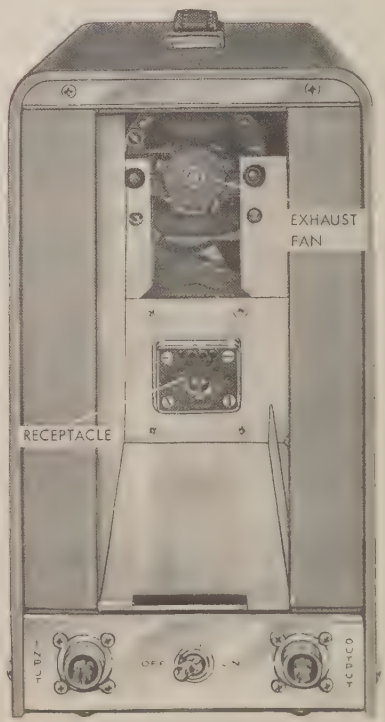


Figure 1-7. Model 195 Cabinet

operating features with the addition of an open-loop provision which permits the user to apply an external feedback network of resistive and reactive elements for specific transmission characteristics, limiting bandwidth, integrating, or generating complex transfer functions.

NOTE

Any Model 111BF Amplifier may be converted easily into a Model 111BFO. (Instructions are included on the schematic diagram.)

1-14. Frequency response of the Model 111 Amplifiers depends on the gain setting. (See Figure 1-8.) The output is up to ±45 volts and/or ±40 milliamperes. (See Figure 1-9.) Chopper stabilization is used for DC amplification, thus avoiding the complexities and operating difficulties of the traditional DC amplifier -- drift is less than 0.000002 volt over 40 hours of operation (after a 15-minute warm up.) A unique four-triode bridge circuit is used in the output stage, affording a very low effective source impedance (less than 1 ohm in series with 25 microhenries) and providing output capabilities for plus and minus voltage or current.

1-15. Operating specifications for the Model 111BF and Model 111BFO Amplifiers are listed in Table 1-1. Each design modification and circuit refinement effected in the family of DC amplifiers has occasioned a stiffening of these specifications.

1-16 APPLICATIONS

1-17. The Model 111 Amplifiers are well suited for use in conjunction with

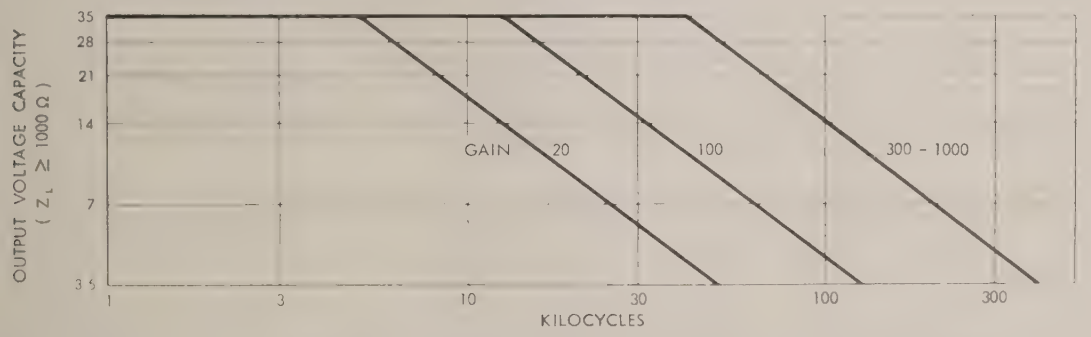


Figure 1-8. Maximum Output Voltage of Model 111 Amplifiers

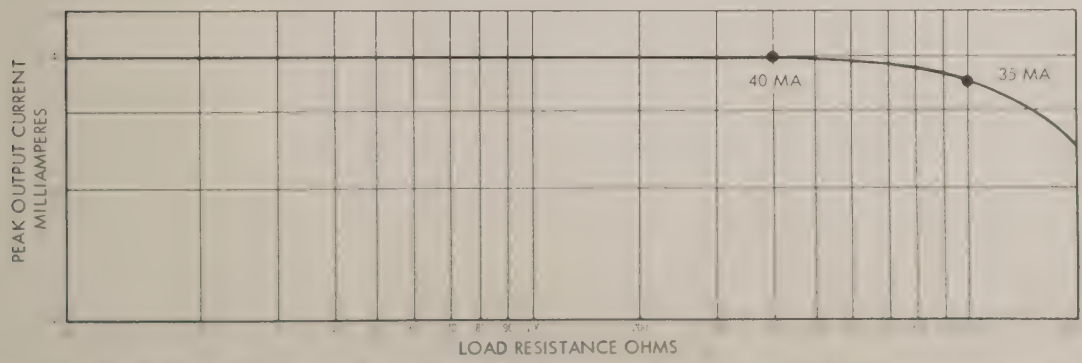


Figure 1-9. Output Current Capabilities of Model 111 Amplifiers

strain gages, thermocouples and other types of transducers to test missiles, aircraft, bridges -- for medical research -- for control of atomic reactors and chemical and industrial processes, and for basic laboratory measurements. Outputs of the amplifiers are applied to voltmeters, recorders, oscillographs, computers, multiplexers, and process control elements. They provide simple maintenance-free operation for all forms of data transmission in regard to strain, pressure, temperature, vibration, flow, displacement, and other physical phenomena. (See Figure 1-10.) They are applied wherever a three-terminal amplifier of precise gain is useful. (Where a four-terminal amplifier is required, the Model 114 Differential Amplifier provides completely effective isolation between input and output grounds.)

1-18. One specialized form of the same basic amplifier has been adapted to the needs of digital voltmeter systems and packaged for mounting as a voltmeter preamplifier. This unit is designated the KIN TEL Model 458 Preamplifier. Details of this unit may be found in technical manual Code No. 2PX-48.

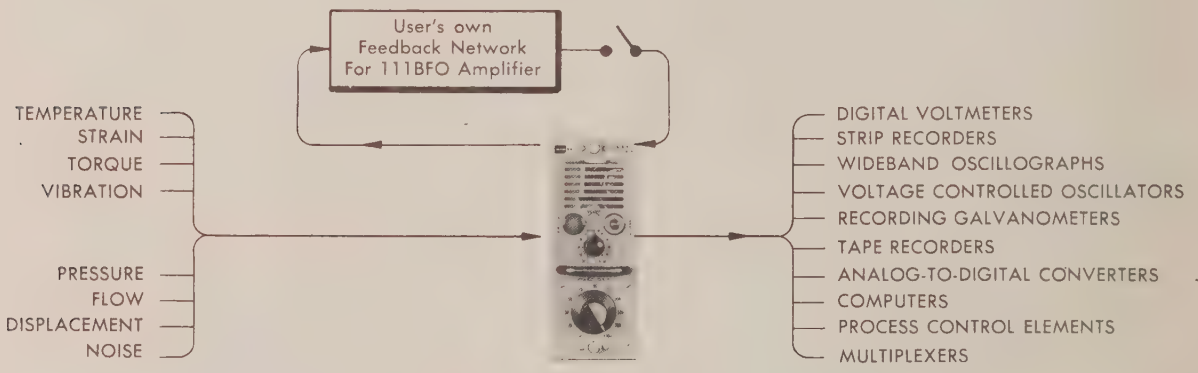


Figure 1-10. Application of Model 111 Amplifiers

Table 1-1. Operating Specifications for Model 111BF and Model 111BFO Amplifiers

GAIN (Phase Inverting)	Steps of 0, 20, 30, 50, 70, 100, 200, 300, 500, 700, 1000, with continuous 1 to 2 times variation of each step by potentiometer.
GAIN ACCURACY	± 0.1db (1.0%) DC to 2kc
GAIN STABILITY	0.1%
INPUT IMPEDANCE	100,000 ohm
OUTPUT IMPEDANCE	Less than 1 ohm in series with 25 microhenries
EQUIVALENT INPUT DRIFT (After Warmup)	Less than ± 2 microvolts for 40 hours or more when used with regulated line voltage, ± 10% change in AC line input causes less than ± 5 microvolt change.
EQUIVALENT INPUT NOISE	0 to 3 cps, less than 5 microvolts peak to peak; 0 to 750 cps, less than 5 microvolts RMS; 0 to 50kc, less than 12 microvolts RMS.
CHOPPER INTERMODULATION	Less than 0.1%
MAXIMUM OUTPUT CABLE CAPACITY	1 microfarad (external)
LINEARITY	Better than 0.1% to 2kc at full output, better than 0.01% at DC at full output.
DC OUTPUT CAPABILITY	Up to ± 35 volts where load resistance is 1000 ohms, up to ± 45 volts where load resistance is 10,000 ohms or above; up to 40 milliamperes where load resistance is between 10 and 400 ohms.
PEAK AC OUTPUT CAPABILITY	± 35 volts from 0 to 40kc on gain ranges of 300 or above, where load impedance is 1000 ohms or greater.
FREQUENCY RESPONSE	±0.1db to 2kc, ±0.3db to 10 kc, less than 3db down at 40kc
RISE TIME	Less than 10 microseconds to 1%
PHASE SHIFT	Less than 5° to 2kc
OVERLOAD RECOVERY TIME	Less than 3 seconds
LEAKAGE RESISTANCE BETWEEN CHASSIS AND SIGNAL GROUND	The impedance between the amplifier chassis (connector pins 4 and 5) and the signal ground leads (connector pins 1 and 11) exceeds 50 megohms at DC and .5 megohms at 60 cycles for floating operation.
POWER REQUIREMENTS	111BF or 111BFO amplifiers: 117 volts (105 to 125 volts), 60 cps, 70VA; 195 Cabinet for single amplifier (1 fan): 117 volts, 60 cps, 15VA; 190 Rack adapter module for 6 amplifiers (3 fans): 117 volts, 60 cps, 45 VA

Section II
INSTALLATION AND OPERATION

2-1 UNPACKING

2-2. The Model 111 Series Amplifiers are shipped in lots of one, two, or three to a carton, installed in a Model 195 Cabinet (singly), never installed in a Model 190 rack module cabinet. Each is wrapped and enclosed in padding in the carton.

2-3. When a single Model 111 Series Amplifier is shipped in a Model 195 single unit type of cabinet, it is tightly clamped in the cabinet, and the associated cable connectors are taped to the AC power cord.

2-4. When several amplifiers are shipped with a Model 190 cabinet, FP190 filler panels should be purchased to occupy any blank spaces. If four amplifiers are shipped, they are wrapped and placed in two cartons of two. The Model 190 cabinet is shipped in a separate carton and the two filler panels are wrapped and placed either within the cabinet or directly behind it by the ventilation ducts.

2-5. When unpacking a shipment, do not discard the calibration sheet which is in a white envelope tucked between the bank of tubes and the vertical metal shield on the right side of the amplifier.

2-6. Unwrap and inspect each item shipped. If a single amplifier is received in a Model 195 cabinet, release the catches at the top and bottom center of the panel (these will be made especially tight for security in shipping and will require considerable torque to loosen), and withdraw the amplifier from the cabinet for inspection and to obtain the calibration sheet.

2-7. If all items appear to be undamaged, set up the amplifier(s) for an operational test as soon as possible.

2-8 SETTING UP

2-9. Instructions and information are included here for setting up the Model 111 Series Amplifier, an amplifier in a Model 195 Cabinet, and a bank of amplifiers in the Model 190 rack module cabinet.

2-10. AMPLIFIER ALONE. The Model 111 Series Amplifiers may be operated in cabinets devised by the user or -- with caution about hum fields and ventilation -- with no cabinet at all. Some difficulty may be encountered with drift as the circuit heats in the absence of a cooling air stream; best results will be obtained if a small fan is directed against the amplifier.

2-11. Connections to the amplifier are made by a special plug -- Cannon DPB-12-34P-2A (KIN TEL Part No. 1310012-1) -- in the rear socket. (See Figures 1-6 and 2-1.) The connector pins are identified in the illustration, and pin connections are listed in Table 2-1.

2-12. AMPLIFIER IN MODEL 195 CABINET. Connections between the amplifier and the Model 195 Cabinet are made automatically by inserting

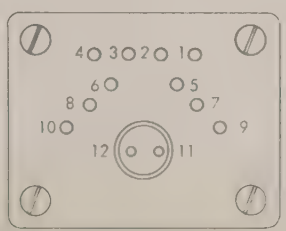


Figure 2-1. Connector at Rear of Model 111 Series Amplifiers

the amplifier. (See Figure 1-7.) Amplifier input and output connections are brought out to two 3-contact connectors at the lower front panel just beneath the amplifier panel. (See Figure 1-2.) An ON-OFF switch on the same cabinet panel controls the 115-volt power to the amplifier. (See Figure 2-2.)

2-13. The amplifier is held within the cabinet by two screw clamps on the front panel. Turning the knurled shaft clockwise for a quarter turn engages the catch behind the lip of the cabinet at top and bottom. Turning the shaft further pulls the latch toward the panel, tightening the amplifier chassis within the cabinet to a considerable degree and preventing any movement. Although the amplifier will not slip out with the latches engaged, it is advisable to tighten the latches snugly with the fingers to the point where shaking the panel handle produces no movement in the amplifier.

Table 2-1. Model 111 Series Amplifier Connections

PIN	CIRCUIT CONNECTION
1	Signal circuit common
2	Shield of operational output
3	Operational output
4	Chassis
5	Shield of output
6	Unused
7	Output return/circuit common
8	115V AC
9	Output signal
10	115V AC
11	Input return/circuit common
12	Signal input

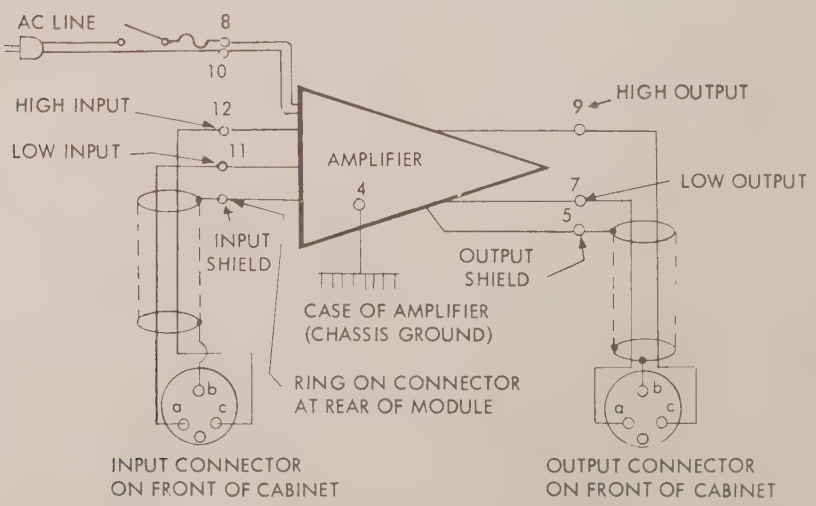


Figure 2-2. Amplifier Connections in Model 195 Cabinet

2-14. Cable connectors to mate with the panel connectors on this cabinet are taped to the AC power cord. These may be installed on the user's cabling.

2-15. AMPLIFIERS IN MODEL 190 RACK MODULE. Up to six Model 111 Series Amplifiers may be installed in a Model 190 cabinet. (See Figure 1-1.) Where fewer than six amplifiers are installed in this rack module, the vacant spaces must be filled with blank panels. Failure to use the blank filler panels will result in improper ventilation for the amplifiers. This cabinet and the amplifiers are set up according to the following procedure:

a. Place the Model 190 Cabinet on a bench, rear side out. (See Figure 2-3.)

b. Loosen the screws directly under the two outside fan vents. Remove the two screws immediately beneath. Remove the plate covering the bottom rear to expose the six amplifier connectors. (See Figure 2-4.)

c. Place the Model 190 cabinet on its side. Use a slot-blade screwdriver on the inside and a No. 4 nutdriver in the rear to remove the lower left (from the rear) screw and nut holding the metal plate on each of the six amplifier connectors. (See Figure 2-5.)

d. Use the same screwdriver and nutdriver to loosen the lower right (from the rear) screw and nut. (See Figure 2-5.)

e. Pull gently outward on the metal plate and allow it to swing downward to the position shown in the dashed lines. (See Figure 2-5.)

f. Remove the fiber washer. (See Figure 2-5.)

g. Tap gently with the screwdriver handle on the center pair of pins (input pins) from the front while pulling on the same pair of connectors from the rear. Remove this input connector, leaving a hole in the complete amplifier connector.

h. Remove this input connector to the bench. Remove the spring cover from the rear by catching a fin-

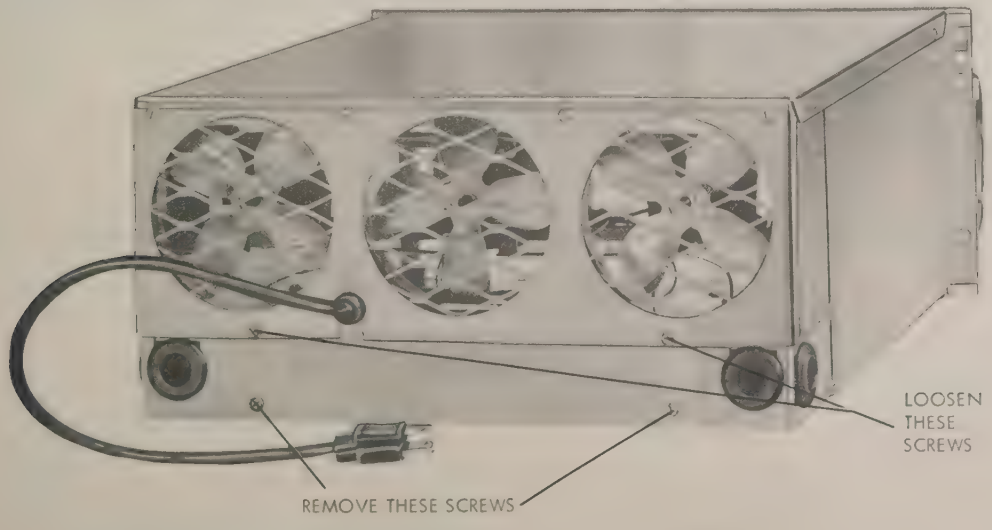


Figure 2-3. Rear of Model 190 Module

gernail in the lap of spring cover over the connector body.

NOTE

Do not confuse this lap with the slot which holds the bent-up lip of the spring cover. (See Figure 2-6.)

i. Use a small iron to solder the already tinned ends of the input leads to the goldplated terminals. (See Figure 2-6.)

j. Solder the shield to the rear of the body of the connector. (See Figure 2-6.)

NOTE

A larger soldering iron may be necessary for a good solder joint on the body of the connector.

k. Replace the input connector in the amplifier connector. Place the fiber washer over the input connector. Swing the metal plate up to hold the connector and washer in place. Tighten screw and nut. Replace the other screw and nut.

l. Repeat steps d through k with each of the other amplifier connectors which will be used.

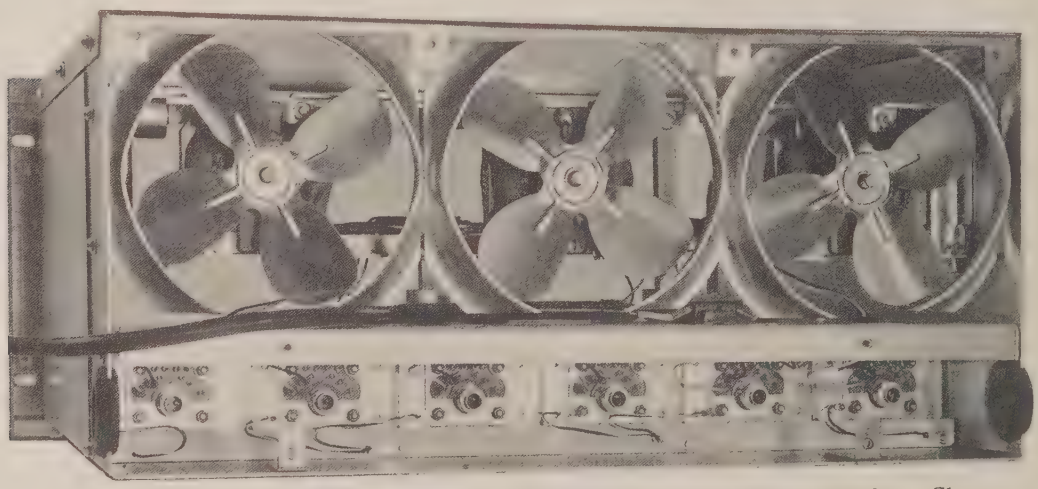


Figure 2-4. Model 190 Rear with Cover Plate Removed to Show Amplifier Connectors

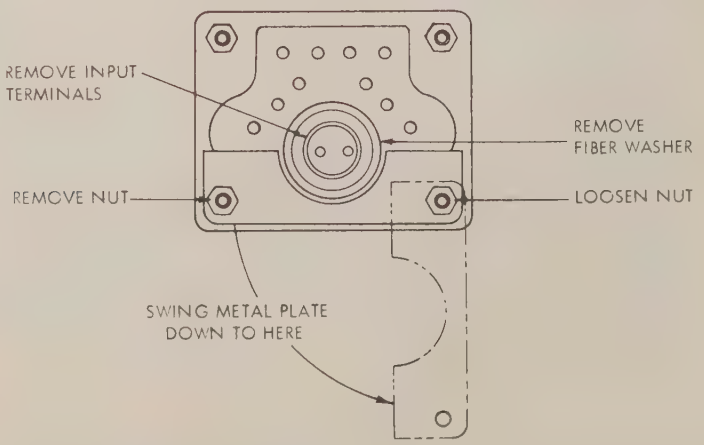


Figure 2-5. Detail of Amplifier Connector (From Rear)

m. Turn the Model 190 Rack Module face down on the bench. Use a small soldering iron to attach output leads. Refer to Table 2-1.

n. Attach output leads for each of the other amplifier connectors which will be used.

o. Pick up the Model 190 cabinet and insert it into a standard 19-inch rack, leading the AC cord and the input and output cabling ahead. Secure the cabinet in the rack with four screws.

p. Insert the Model 111 Amplifiers one-by-one into the Model 190 cabinet. Make sure that the short guide strip projecting up from the bottom surface at the rear in each amplifier's position engages the alignment slot in the rear bottom plate of each amplifier.

q. Rotate the amplifier panel latch shafts clockwise a quarter turn at top and bottom. Turn the shafts further to tighten the latches and pull the amplifier firmly into each connector at the rear.

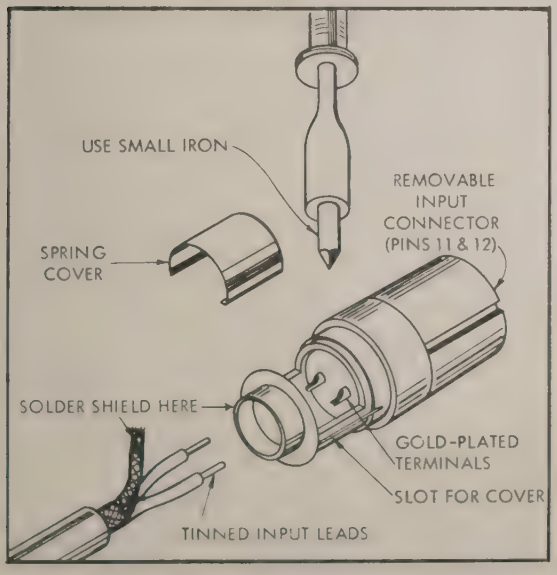


Figure 2-6. Wiring Input Leads

r. Insert blank filler panels as necessary to fill the front opening of the Model 190 cabinet.

2-16. It may be necessary to fasten the amplifiers to wiring already existing within the rack, making it impractical to wire input and output connections with the Model 190 cabinet on the bench. In this case, the output connections should be attached first, and then the input connector removed and leads attached in midair behind the rack. This activity will require two persons to remove and replace the connector -- one to hold the screwdriver from the front, the other to work the nutdriver from the rear -- and two to hold the connector and solder the input leads.

2-17. Before completing the wiring of an intricate installation, it is well to make an initial breadboard-type of amplifier connection for conducting a simple performance test to determine whether the amplifiers are functioning normally.

2-18. SIMPLE OPERATIONAL TEST. A simple operational test of the Model 111 Series Amplifiers can be made with a single cell battery and a standard voltmeter. (See Figure 2-7.) The procedure is as follows:

a. Switch on amplifier. The red pilot lamp should glow.

b. Adjust the gain switch to the 20 position.

c. Connect the single cell to the amplifier input in either polarity.

d. Measure the output voltage. If the input level is +1.4 volts, the output should be -28 volts. If a

-1.35 bias cell is used, the output should be +27 volts.

2-19. More exacting tests of the amplifier follow the same configuration but involve increased nicety in determining input and output voltage.

2-20 AMPLIFIER CONNECTIONS

2-21. Although the bare facts of input and output connections are disclosed in the preceding paragraphs, the Model 111 gain and bandwidth are sufficiently high to require special considerations in connecting into existing metering instrumentation. Use of a single amplifier with close-by components and simple, direct wiring is uncomplex enough for direct connections according to the Table 2-1 data. Many installations, however, are vastly more intricate, and care must be used to avoid noise, oscillation, and overloading difficulties.

2-22. INPUT SHIELD. The shielding of the input cabling should be tied only to the ring at the rear of the input connector. (See Figures 2-6 and 2-8.) When the amplifier is used with the Model 195 cabinet, this shield is connected to pin b, the upper center pin in the input connector at the lower left front of the cabinet. In the Model 190 cabinet, the input shield should be tied only to the ring of the appropriate input connector -- to no other pin on the complete amplifier connector.

2-23. OUTPUT SHIELD. The output shield is brought out to pin b, the upper center pin, on the lower right corner of the Model 195 cabinet. In any installation that does not involve input and output shields being connected to each other or to conduits or to other ground, this shield connection may be carried through to whatever device the amplifier operates into. Where the installation is more complex and involves possible common grounding for input and output shields, the ensuing ground loops set up circulating currents, increase noise and hum, and can cause the amplifier(s) to oscillate.

Figure 2-7. Operational Test

2-24. These ground loops may be avoided by connecting the output shield to the low side of the output terminal. (See Figure 2-8.) In the Model 195 cabinet, this involves connecting both shield and low inner lead to pin a. In the Model 190 rack module, both shield and low inner lead should be tied to pin 7. Insulated cables should be used to avoid spurious ground connections between the shields wherever possible.

2-25. OUTPUT CAPACITY. The output load on the amplifier is a part of the inverse feedback circuit; hence the character of the load affects the nature of the feedback signal. Excessive capacity in the output circuit reduces the margin of amplifier stability and impairs the ability to recover from over-

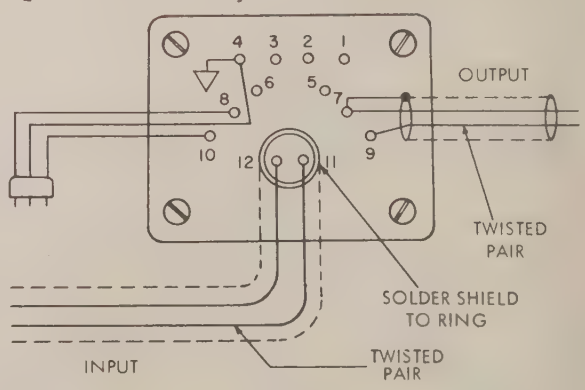


Figure 2-8. Amplifier Connections to Avoid Ground Loop Oscillation

loads. In extreme cases, oscillation results. Use of the amplifiers with highly capacitive loads may require strapping the output with a resistance or, in extreme cases, insertion of a capacitive voltage divider in the output line.

2-26. The earlier models of these amplifiers are more sensitive to output capacity than the late units. Model 111, Model 111A, Model 111AF, and Model 111AFO Amplifiers were all designed to work into a load having a capacitance of less than 0.02 microfarad, and should be strapped to 1000 ohms at the output terminals. The Model 111BF and Model 111BFO Amplifiers are significantly less sensitive to capacity and function well with cable and load capacities as high as 0.5 microfarad without strapping.

2-27. Figure 2-9 shows the type of voltage divider that may be required with loads having very high capacity. The constants to be used in the divider circuit are determined by the particular load impedance which is applied to the amplifier. The load resistance, R_L, and the load and cable capacitance, C_C, are the controlling parameters.

2-28. The series capacity, C_1, should be selected to cause the total series capacitance, C_1 and C_C, not to exceed 0.01 microfarad for the early model amplifiers or 0.2 microfarad for the Model 111BF or Model 111BFO Amplifier. Explicitly, the procedure is as follows:

a. Measure the total cable and load capacitance by means of an impedance bridge or Q meter.

b. Select C_1 for the early model amplifiers equal to

$$\frac{C_C}{100\ C_C - 1},$$ or for the

Model 111BF or Model 111BFO Amplifiers equal to

$$\frac{C_C}{5\ C_C - 1}.$$

2-29. The series resistance, R_1, is selected to have a ratio to the load resistance, R_L, equal to the ratio of reactances in the capacitive divider. Explicitly, the procedure is as follows:

a. Determine R_L.

b. Select R_1 equal to

$$\frac{R_L \times C_C}{C_1}.$$

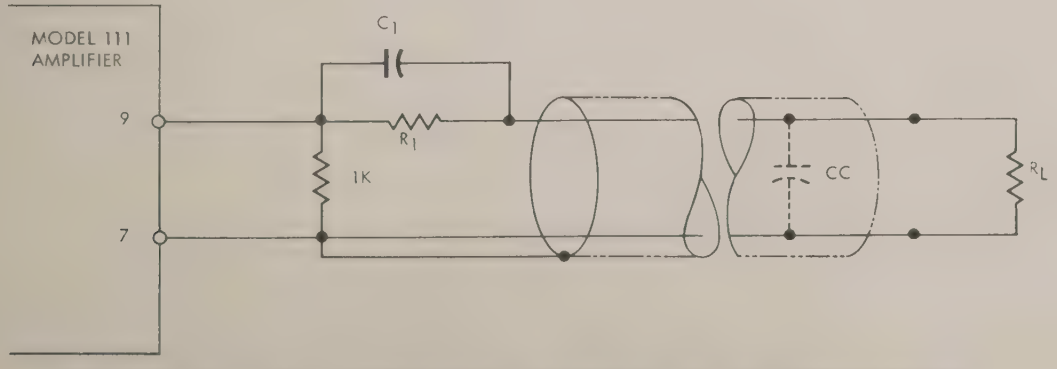


Figure 2-9. Capacitive Voltage Divider in Amplifier Output

2-30. WIRING OF ASSOCIATED CIRCUITS. Although the amplifier will operate within specifications in virtually any installation if connected as indicated in Figure 2-8. the most satisfactory results will be obtained -- particularly in respect to noise and hum -- if each amplifying channel is grounded in one spot only. This principle applies to shielding as well as to the signal grounds. If either a line or a shield is tied to ground at two points, a loop is formed, and heavy currents can be induced in these loops by simple magnetic pickup from the fields of motors, transformers, and other circuits. Even in a shield, this condition is undesirable since the balance of a twisted pair is never perfect and a portion of the spurious signal will appear in the signal circuit. Also, artifical unbalances can be introduced into transmission lines by calibrating networks. Thus, even though the signal circuit may be completely floating, loops formed by multiple grounding of a shielding system can degrade the performance of an amplifying channel.

2-31. VENTILATION. Each amplifier is equipped with slots in the panel to permit cooling air to be drawn and exhausted via fans in the rear of the Model 195 Cabinet and the Model 190 Rack Module. To assure proper ventilation, do not cover these slots with calibration tags or stickers. Also, the heated air exhausted from the cabinets must be permitted to be expelled from a closed rack cabinet.

2-32. If fewer than six amplifiers are used in a Model 190 cabinet and other equipment is installed in the rack module, be sure that the other equipment neither impedes the flow of air nor invalidates the draft by being completely open (resulting in air not drawn in through the vent holes).

2-33 OPERATION

2-34. Operation of the Model 111 Series Amplifiers is clear and straightforward. Switching on AC causes the pilot lamp to glow on the panel. The gain may be selected by the multiposition tap switch on the panel. The indicated gain is obtained with the vernier gain control in the extreme counterclockwise position within the accuracy listed in the specifications (refer to Table 1-1.) The only instructions needed relate to warming up, balancing, and use of the operational open-loop potentials of the amplifier.

2-35. WARMING UP. Permit the Model 111 Series Amplifiers to reach equilibrium temperature; warm up for at least 30 minutes for any exacting use.

2-36. BALANCE. To balance the Model 111 Series Amplifier, short-circuit the input and adjust the BALANCE screwdriver control on the panel for zero output as measured on a DC microvoltmeter. (See Figure 2-10.) For the final adjustment switch the microvoltmeter to a very sensitive range.

2-37. After the initial adjustment of the BALANCE control, rebalancing is seldom required unless the amplifier operating conditions are altered. If it is desired to rebalance the amplifier, a sensitive indicating device is required because the zero drift over a long period is of the order of 2 micro-

Figure 2-10. Setup for Adjusting BALANCE CONTROL

volts of equivalent input. (On a 1000X gain setting, a 2 microvolt equivalent drift would cause an output voltage of 1000 times 2 microvolts or 2 millivolts.)

2-38. OPERATIONAL USE. The Model 111BFO amplifier has an open-loop position (zero-gain position) to permit the user to connect an external feedback circuit for a special operational condition. (The Model 111BF amplifier may be converted to operational usage by circuit changes indicated on the schematic diagram.) This feedback circuit may be resistive or reactive to achieve a particular transfer function. By selecting the proper components, it is possible to obtain a special gain, to cause the amplifier to act as an integrator, to limit the amplifier bandwidth, or to generate a complex function.

2-39. EXTERNAL FEEDBACK CONFIGURATION. The configuration of the external feedback loop will be basically as shown in Figure 2-11. The components which may be added are designated Z_i for input impedance, Z_o for output impedance, and a feedback factor, β, which is selected by

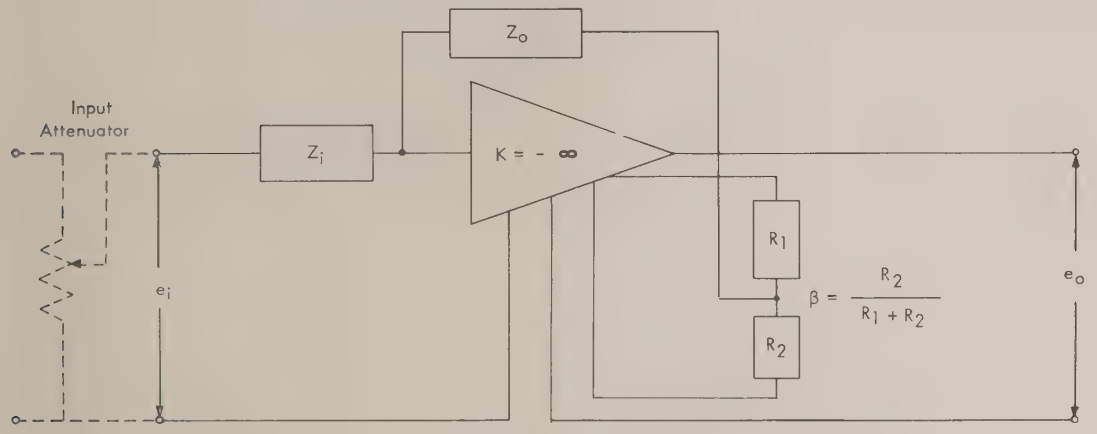


Figure 2-11. Operational Connection of Amplifier

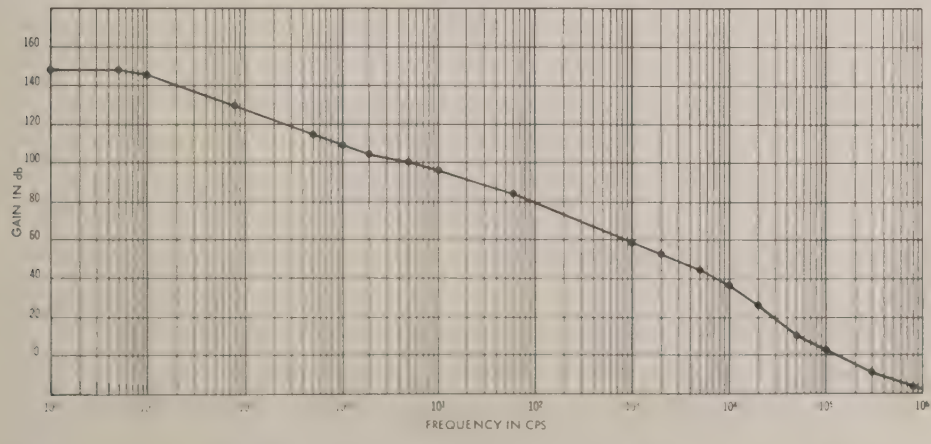


Figure 2-12. Model 111 Amplifier Gain vs Frequency (Typical)

the ratio of the divider resistors, R_1 and R_2. In addition, an input attenuator may be used. In this type of circuit, the gain can be expressed as

$$\frac{e_o}{e_i} = \frac{-Z_o}{\beta Z_i}$$

where e_o is the output voltage,
e_i is the input voltage, and
$0 \leq \beta \leq 1$.

2-40. OPEN-LOOP GAIN. The gain of the Model 111 Series Amplifiers in an open-loop condition varies inversely with frequency. (See Figure 2-12 for a typical gain characteristic plotted against frequency.)

2-41. EXAMPLES OF OPERATIONAL USE. Table 2-2 lists a few basic examples of operational use with their corresponding input and feedback impedances. The letter p represents a small signal change with respect to time:

$$p = \frac{de}{dt}, \quad \text{and the reciprocal}$$

of p is the integral of a small change with respect to time:

$$\frac{1}{p} = \int dt.$$

2-42. The impedance of Z_o in Table 2-2 must include sufficient capacity to corner at or below 50 kc. The impedance of β must then be such that it is capable of driving Z_o well beyond 50 kc. Many types of operation can be achieved by using different values of Z_i and Z_o with appropriate dividers in the output circuit.

2-43. INSTALLATION OF OPERATIONAL COMPONENTS. Operational components may be connected directly to the amplifier connector. (See Fig-

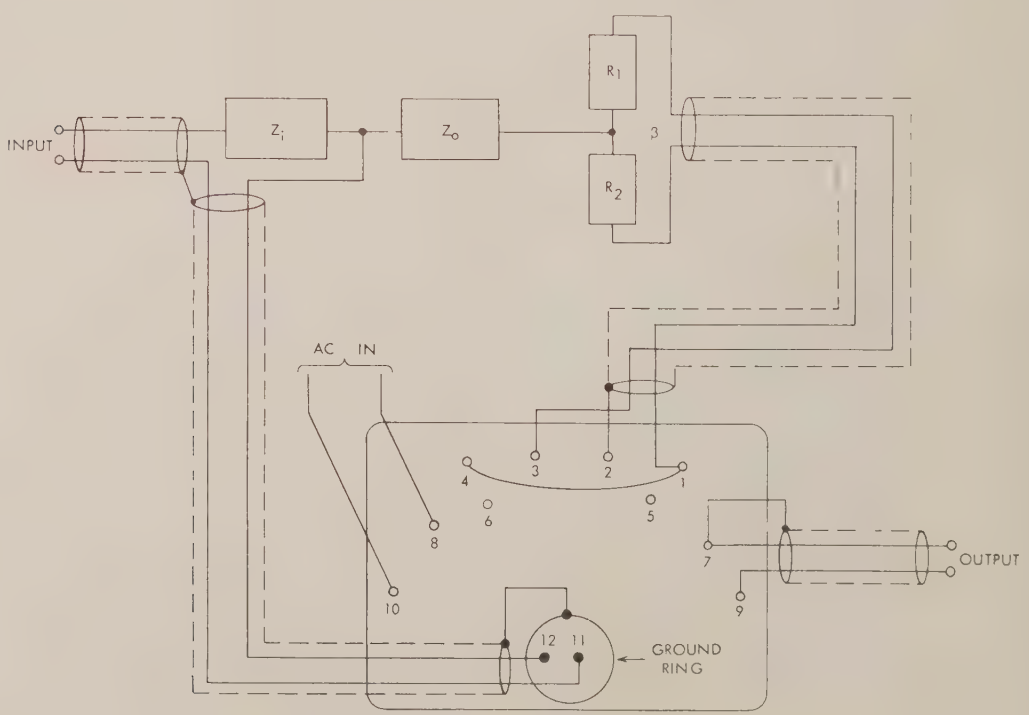


Figure 2-13. Installation of Operational Components

ure 2-13.) All leads should be shielded. Use special care in shielding the point where Z_o, Z_i, and the amplifier input are tied together. To prevent ground-loop problems, the shields should be grounded at one end only. Leads to the constants should be as short as possible to minimize the addition of capacity -- especially at the junction of Z_o, Z_i, and the amplifier input.

Table 2-2. Impedances and Characteristics for Typical Operational Use

Z_i	Z_o	Transfer Characteristic	Use
R_i	R_o	$\frac{-R_o}{R_i}$	1. Scale Change (amplification) 2. Sign Change (phase inversion) 3. Impedance Transformer
R_i	C_o	$\frac{-1}{R_i C_o p}$	Integrator
R_i	C_o in parallel with R_o	$\frac{-R_o}{R_i} \quad \frac{1}{1 + R_o C_o p}$	Low pass filter $F_{cut\text{-}off} = \frac{1}{2\pi R_o C_o}$

Section III
THEORY OF OPERATION

3-1 OVERALL FUNCTION

3-2. The overall function of the Model 111 Amplifiers is to provide precisely known gains for minute direct currents having AC components extending into and past the range of audibility. (See Figure 3-1.) This is accomplished by three amplifiers that work together, K_1, K_2, and K_3. The first two amplifiers, K_1 and K_2, are paralleled and receive the same input signal. One of these, K_1, is a wideband audio unit that receives only the AC components of the signal -- direct currents are blocked by a capacitor -- and amplifies these components without altering their polarity. The output is applied to a summing junction.

3-3. The second amplifier, K_2, is a chopper-stabilized unit that amplifies only DC and very low frequencies. This amplifier also applies its output to the summing junction, and this output also is of the same polarity as the input, therefore can be mixed with AC components that are amplified in K_1. (These amplifiers are marked + in Figure 3-1 to signify that no change in polarity occurs.)

3-4. The recombined signal is fed to the last amplifier, K_3, which acts on all components of the signal, DC, very low frequencies, and AC through and beyond the audio band. This amplifier alters the polarity of the DC and reverses the phase of the AC components in order that the feedback applied around the overall circuit will be degenerative -- hence stabilize the amplification. (Consequently this amplifier is marked - in Figure 3-1.) The amplifier output is taken from an extremely low impedance circuit so that loading from a following metering or recording device will not have any significant effect on amplification or the characteristics of the signal structure.

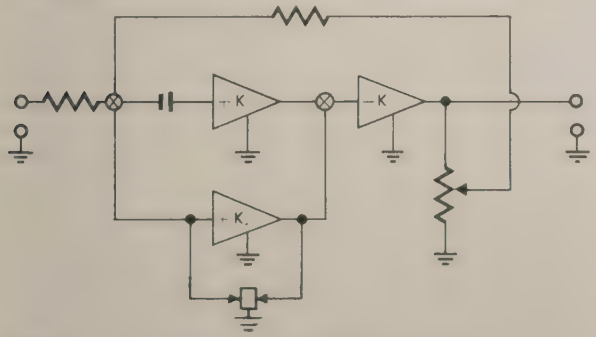


Figure 3-1. Overall Block Diagram of Model 111 Amplifier

3-5. A portion of the output signal is tapped off in a voltage divider and applied as inverse feedback to the amplifier input. By varying the constants in this voltage divider, the proportion of the output signal fed back to the input is changed. The resulting change in degeneration alters the amplification. The feedback constants are selected to provide the fixed gains marked on the front panel. In all positions, the total amount of feedback applied around the circuit is so large that the amplifier is not sensitive to changes in power line voltage or to alterations in vacuum tube characteristics as a result of aging.

3-6 DETAILED OPERATION

3-7. The Model 111 Amplifier circuit uses six amplifying stages, an output bridge, three summing junctions, a chopper, a driven diode demodulator, and a feedback network to perform its function. (See Figure 3-2.) These elements are arranged to amplify only

AC components in a high frequency amplifier, K_1, DC and low-frequency AC components in a paralleled amplifier, K_2, and the reconstituted signal in a final amplifier, K3.

3-8. INPUT SUMMING JUNCTION. The input signals applied to the amplifier are fed to summing junction SJ1. This junction is not a specific circuit component -- merely a point where input and inverse feedback signals are applied and from where signals are taken for the inputs to the high frequency amplifier, K_1, and the DC and low-frequency amplifier, K_2.

3-9. HIGH FREQUENCY AMPLIFIER. The high frequency amplifier, K_1, receives signals over 1 cycle per second -- lower frequencies are blocked by C305. The amplifier consists of one triode section of V303 which is capacitively coupled to V302, a high gain pentode 6AU6.

3-10. Summing junction SJ2 -- another point, not a circuit component -- is located between the two stages of amplification. A portion of rectified signal from the DC and low frequency amplifier is applied here to provide an operating reference, stabilize the high frequency amplifier, and improve overload recovery time. The output of V304 is coupled by C316 to a third common point, SJ3.

3-11. DC AND LOW FREQUENCY AMPLIFIER. The input signal at SJ1 is brought down through R343 to the chopper and the input to the DC and low frequency amplifier. The chopper grounds this signal 60 times each second, hence the DC is transformed into a modulated 60-cps carrier which can be amplified as an ordinary audio tone for subsequent demodulation.

3-12. After being amplified in V303B and V308A, this carrier is isolated

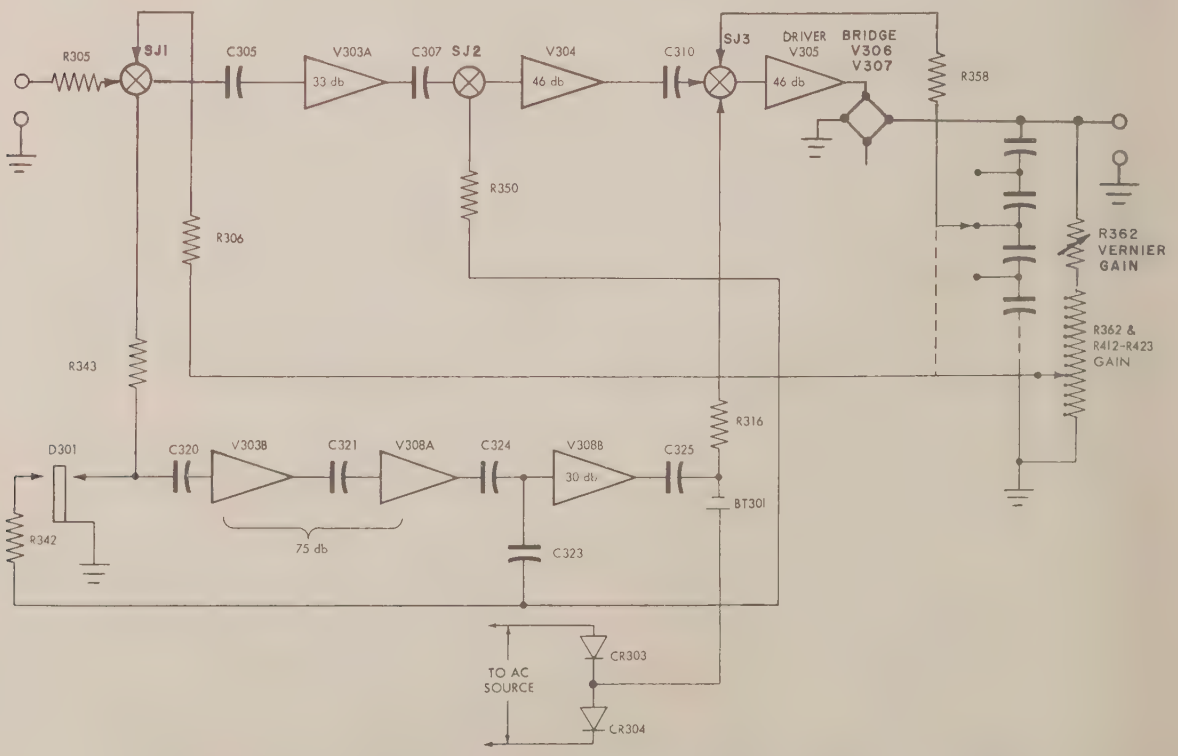


Figure 3-2. Circuit Configuration of Model 111BF Amplifier

from ground reference by the coupling capacitors. The other chopper contact is used for synchronous rectification of a portion of the signal, and the resulting DC is applied to SJ2 as stated in paragraph 3-10. The carrier is not materially affected by this tapping off of a stabilizing signal but is amplified further in V308B, then synchronously rectified by driven diode demodulators CR303 and CR304. The DC output is applied to SJ3 where it is mixed with the AC components amplified in V303A and V304.

3-13. FINAL AMPLIFIER. The reconstituted signal is applied to the final amplifier which consists of an output driver V305 and a bridge circuit using four triodes, V306 and V307. After amplification in K_1 and K_2, the signal is so large that noise, hash and drift inherent in traditional DC amplifiers cannot affect the signal beyond a negligible degree; consequently both DC and AC components are amplified in V305. This stage alters DC polarity and inverts the AC signal phase.

3-14. The amplified signal is applied across the output bridge which is balanced against ground with zero signal. The output may be either positive or negative and has an impedance lower than 1 ohm. The output from this bridge is the output of the Model 111 Amplifier.

3-15. FEEDBACK NETWORK. The output of the final amplifier $-K_3$ is applied to a resistive-and-capacitive voltage divider which taps off two signals for feeding back to SJ1 and SJ3. The overall feedback loop to SJ1 encloses the resistive voltage divider. Because only resistance is involved, this loop is not frequency selective, hence can be used as gain control. The resistive divider is one complete wafer of the gain selector switch on the front panel. Ganged with this resistive divider is another formed of capacitors which is in the feedback loop around the final amplifier. This divider is frequency selective, hence the feedback through R358 to SJ3 stabilizes the final amplifier and simultaneously controls the frequency response as indicated earlier (Figure 1-8).

3-16. On the latest model of this amplifier (111BF) a small additional control (R362) is incorporated in the resistive feedback network. This control is the vernier gain adjustment on the front panel.

3-17. The operational models of the amplifier (111AFO and 111BFO) open the resistive feedback loop entirely in the fully counterclockwise position for open-loop amplification. In this position, the frequency response is as shown earlier (Figure 2-12) with no external feedback loop connected. The capacitive feedback loop enclosing the final amplifier is still connected in this operational position, resulting in a gradually decreasing amplification with increasing frequency. (See Figure 2-12). From a gain of more than 140 db at 0.01 cps, the characteristic shows a decline to unity gain at 100 KC.

3-18 CIRCUIT THEORY

3-19. More detailed explanations are given here for the less conventional features of the amplifier circuit. (Reference may be made to the schematic diagram.) Theories are presented for the chopper amplifier principle, the driven diode demodulator in this application, the output bridge circuit.

Brief statements are made also regarding the AC amplification, feedback application, overload protection, balancing circuit, and power supply.

3-20. CHOPPER AMPLIFIER. The application of a chopper and a narrow-band 60-cps amplifier for direct currents permits handling without the noise and drift commonly encountered in DC amplification. The chopper itself is a vibrating reed driven by a coil at 60 cps. Contacts on each side are made and broken. Placed in a position to ground a direct voltage at the input of an amplifier, it converts a smooth potential into a pulsating 60-cps signal with square-topped waveform as shown in the diagram. (See Figure 3-3.) At the moment of consideration, the input signal is grounded and the waveform is at the instant marked by the dashed line and asterisk.

3-21. This chopped 60-cps signal is amplified in a capacity-coupled circuit that removes any ground reference, and the output of the second triode is in phase with the input signal. However, this output signal is grounded by the chopper reed on opposite excursions so that this amplified signal is tied to ground at the top. Moments when the signal is ungrounded (as at the asterisk and dashed line) are occasions of negative peaks of DC. Filtering with a capacitor results in a smooth amplified direct current of a polarity opposite to that of the battery shown at the input to the amplifier. Reversing the input polarity will cause a positive output.

3-22. In this particular application, the battery is replaced by an input signal to be amplified. Also the output chopper contact grounds the amplified signal through a large resistance instead of directly. Thus the 60-cps square-topped signal can be amplified further for synchronous rectification by another means. Such additional amplification inverts the phase of the 60-cps signal so that the final rectification results in a signal of the same polarity as that applied to the input.

3-23. The chopper-rectified signal is applied as a reference to SJ2 (see Figure 3-2) where the AC signal is inverted in phase by having passed through V303A. The pulsating AC is fed through a bias cell to adjust the level and through R350 which acts as a grid resistance for the second stage of AC amplification. This resistance also acts as the series element in an RC filter, the filtered DC appearing

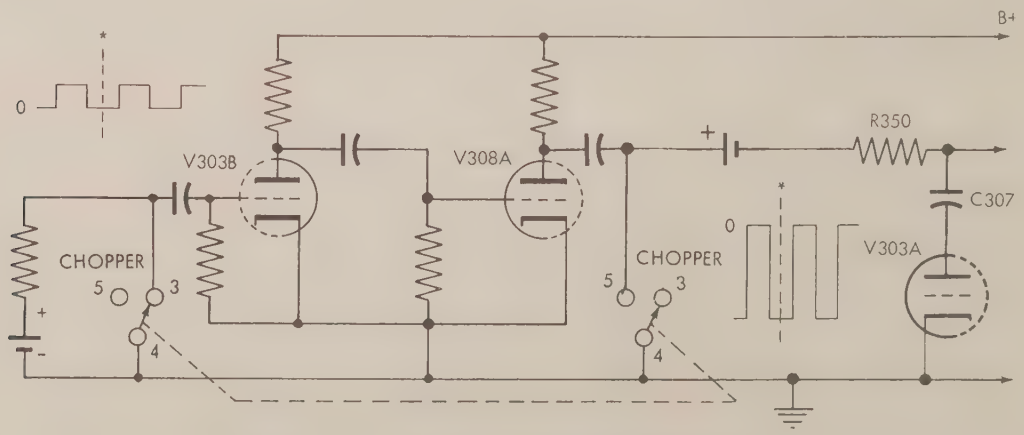


Figure 3-3. Chopper Amplifier Circuit

across C307 and the plate resistance of the triode V303A. This filter smooths the 60-cps pulsation into a steady reference, stabilizing the high frequency amplification in K1. This reference signal is applied through a resistive voltage divider whose series arm is shunted by a neon bulb, I303. (See Figure 3-4.) This bulb will flash with a potential of 60 volts across R349 -- an occurrence that cannot happen with any in-range input signal. Applying a large over-range voltage to the Model 111 will make this bulb flash, shorting out R349 and increasing the reference level by a factor of approximately 8. This increased DC reference discharges C307 (which was charged by the overrange signal), and facilitates recovery from overload in both C307 and C310.

3-24. The 60-cps pulsating signal is amplified further (and inverted in phase) in V305, then synchronously rectified in the driven diode demodulator circuit.

3-25. DRIVEN DIODE DEMODULATOR. The amplified 60-cps square-topped signal is rectified by a driven diode demodulator which is essentially a bridge circuit. (See Figure 3-5.) When the phase of the 60-cps exciting voltage is as shown, the diodes conduct and the bridge is balanced. The junction of the diodes is then at the same potential (approximately) as the junction of the resistors which is grounded. Hence, point X is essentially at ground at the moment indicated by the dashed line and asterisk. The result is a positive 60-cps pulsation which is smoothed by the filtering action of the series resistor, R316, and the combination of C310 and V304 plate impedance. The level applied to the grid of V305 (SJ3) is smoothed as shown at the dashed line in the lower right corner of the illustration. The polarity of the signal is the same as that at the input to V303B, hence can be mixed with the high frequency signal that has been amplified proportionately and is of the same phase as that applied to the input of V303A. This mixture takes place at SJ3 and results in a completely reconstituted signal suitable for amplification in V305.

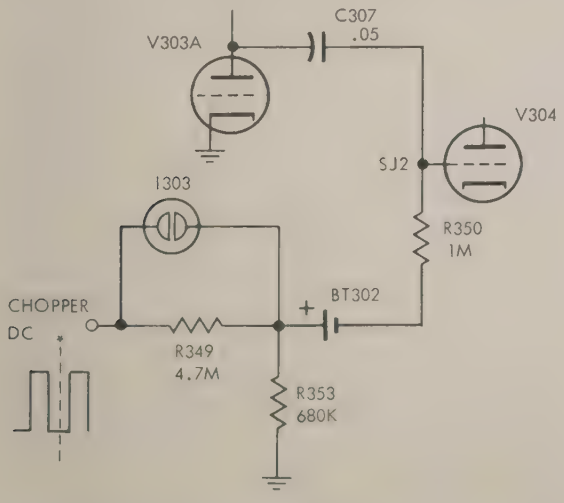


Figure 3-4. Overload Protection Divider in Reference Circuit

3-26. The bridge is shown receiving its excitation voltage from a 60-cps generator. In practice, this bridge is excited by a winding on the power transformer, phased properly for synchronous rectification.

NOTE

In the event that the power transformer should be replaced, this excitation winding must be phased with the chopper coil excitation.

3-27. The combined signal is amplified by the conventional DC amplifier, V305. This stage inverts the signal

(hence the amplifier is referred to in Figure 3-1 as $-K_3$.) The amplified signal is applied to the output bridge circuit. In order to avoid high frequency loss from this pentode amplifier, the output is taken from a voltage divider whose series arm is shunted with a capacity. The values are selected to effect a mild boost between 300 and 1000 cps.

3-28. OUTPUT BRIDGE CIRCUIT. The amplified DC, low frequency and high frequency AC appears across a balanced output stage in the form of a bridge having triodes in each of the four sides. (See Figure 3-6.) The signal is applied to the bridge against a B negative of -150 volts, while the triodes have a B positive of +200 volts. The output is taken across the midpoints of the arms, can be either negative or positive, and can be either a low impedance voltage or an output current.

3-29. As the DC level applied to the upper left triode, V306A, becomes more positive, current increases and the voltage at the junction of R322 and R326 becomes more negative. This voltage change is applied through voltage dividers to the grids of V307A and V306B, reducing the flow of current through those triode sections and through R331. However, this results in a more positive signal at the plate of V306B (hence a more positive grid voltage for V307B) and a decreased cathode bias for V307B. The current through V307B consequently increases and balances that through the other arm, and the difference flows through the load itself.

3-30. The symmetry of the bridge assures equal voltages at the midpoints of the arms when the bridge is balanced. Since the right arm midpoint is tied to ground, the left arm swings both positive and negative de-

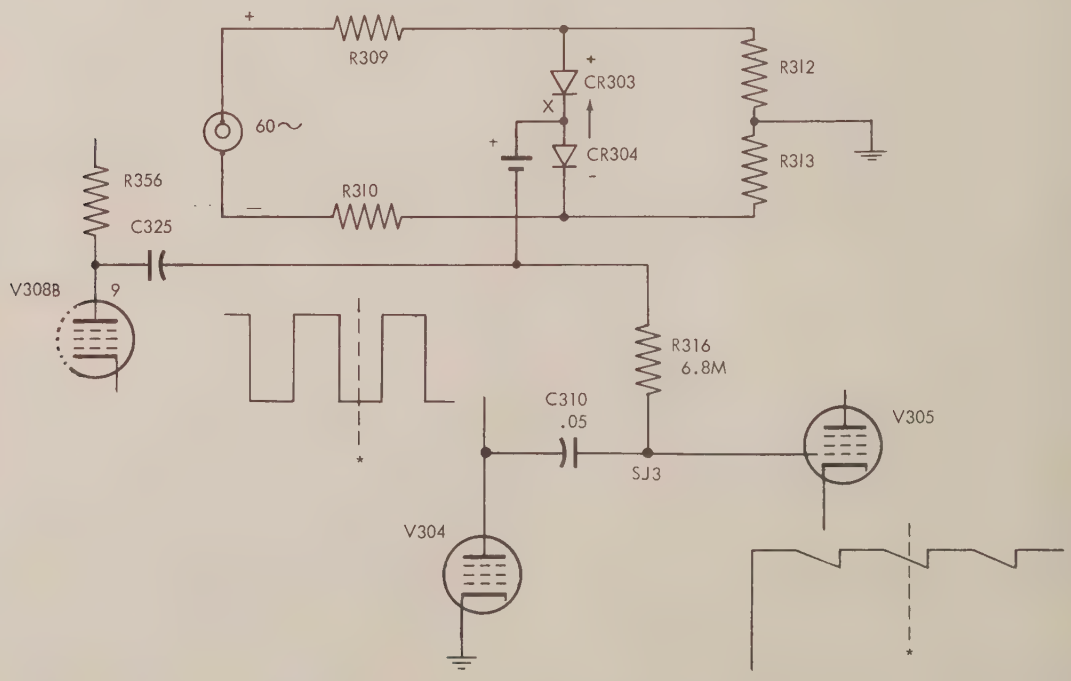


Figure 3-5. Driven Diode Demodulator Circuit

pending on the polarity of the voltage applied to the grid of V306A. The amplitude of this applied voltage determines the excursions of current flow, but always an increase of current in the input triode is accompanied by a decrease in adjacent triodes and an increase in the opposite triode. Thus the amount of current drawn by the bridge remains essentially constant, and no change in balance follows a change in the applied B and B- voltages.

3-31. A neon bulb is tied across the two top triode plate circuits and will flash at approximately 60 volts. The accompanying circuit constants have been selected to cause this flashover to occur just before an increasing signal reaches the overload point. This bulb is on the front panel as an indicator of imminent overload -- not of an existing overload.

3-32. AC AMPLIFICATION. The higher frequency components are amplified in V303A, V304, and V305. The first two of these are conventional audio amplifiers -- triode and pentode -- and V305 is a conventional DC pentode amplifier. The pentode plate and screen resistances have been selected to assure high gain and low phase shift to beyond 100 KC. Crystal diodes CR305 and CR306 are used in a network across the input triode, V303A, that decreases the plate loading with increasing frequency -- beginning at about 150 cps and shunting the tube

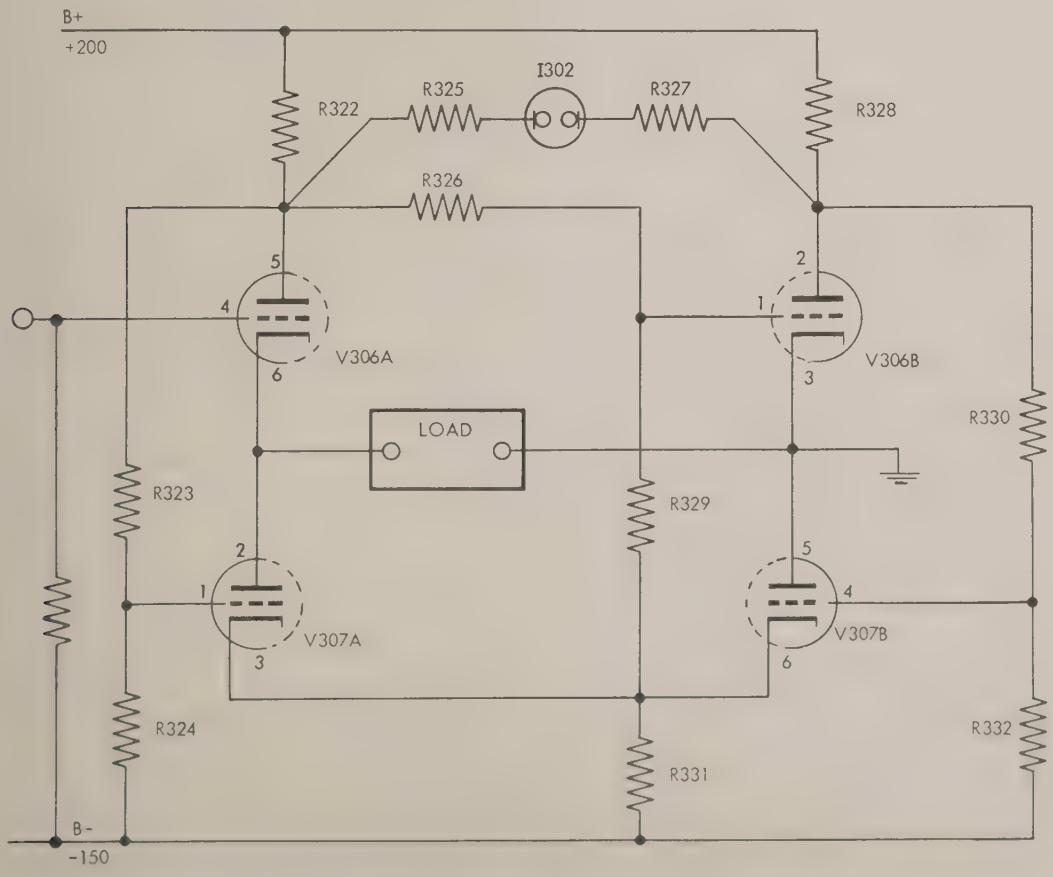


Figure 3-6. Output Bridge Circuit (Simplified)

down to its own plate resistance at about 80 KC. (This circuit also offers some protection from overloading voltages.)

3-33. Triode sections V303B and V308A amplify only 60 cps signals, as does the pentode V308B. Plate and screen resistance of this latter tube are appreciably higher than with the wideband pentode amplifiers, consequently, this tube provides greater gain.

3-34. FEEDBACK/GAIN. Open loop gains for the various stages are shown in Figure 3-2. Total amplification is 151 db for DC and low frequencies, 165 for high-frequency components. Fixed gain steps are provided in the feedback network for amplification ranging from 10 to 60 db overall. With the vernier gain control having an influence of roughly 2:1, the total range of overall amplification is then from 4 db to 66 db. The difference between the total of open loop gains and these overall gains is the amount of feedback. It is seen that the feedback factors in even the highest gain settings are more than sufficient to make the amplifier insensitive to changes in tube characteristics or applied potentials.

3-35. The amount of feedback also extends the frequency response of all portions of the circuit enclosed in the loop and linearizes the amplification.

3-36. OVERLOAD PROTECTION. Three circuits protect the amplifier from the ill effects of overloading by application of out-of-range signals. The overload indicator on the panel is a neon bulb between triode sections of the output bridge circuit. Refer to paragraph 3-31. Another neon bulb is placed in a voltage divider of the DC reference circuit. Refer to paragraph 3-23 and see Figure 3-4. This circuit aids recovery from overloading the AC amplifier and prevents loss of signal as a tube bottoms or tops. A pair of inverted diodes are used in a shunt loading circuit on the input triode, V303A, to eliminate high frequency transients of excessive amplitude. Refer to paragraph 3-32.

3-37. BALANCING CIRCUIT. A network of resistors is placed between the +200 and -150 volt lines to the output bridge. (See Figure 3-7.) A balancing potentiometer selects a voltage between +0.3 and -0.35 to be applied to the input contact of the chopper in order to balance out any offset that might exist in the DC potential to be amplified. This potentiometer is marked BAL on the front panel.

3-38. POWER SUPPLY. Power to operate the Model 111 Series Amplifier is taken from a transformer with several windings and operating with three separate rectifiers. The first of these is a conventional full-wave circuit furnishing +360, +320, and +240 volts for operating V304, V305, V303 and V308. The rectifier plate winding associated with this supply also provides the 60-cps voltage for synchronously rectifying the pulsating DC signal (refer to paragraph 3-25.) The voltages furnished by this supply are returned to ground.

3-39. Another full-wave rectifier circuit provides +200 volts and -150 volts for the output bridge. Refer to paragraphs 3-28 through 3-31.

3-40. Another winding is used with crystal diodes CR301 and CR302 to furnish +12 volts for the heaters of V303 and V304. Use of DC heater

excitation avoids hum in the high-frequency amplifier.

3-41 OPEN-LOOP OPERATION

3-42. The operational amplifiers (Model 111AFO and 111BFO) have a slight circuit difference from the standard models. The resistive feedback circuit is opened (making the vernier gain control inoperative) to permit use of an external network for achieving a specialized transfer characteristic. The capacitive feedback circuit is still in effect and serves to stabilize the output amplifier.

3-43. Model 111AF and 111BF amplifiers may easily be modified to the operational type of amplifier by removing two jumper leads, adding a third. Details of this modification are shown on the schematic diagram at the back of this manual.

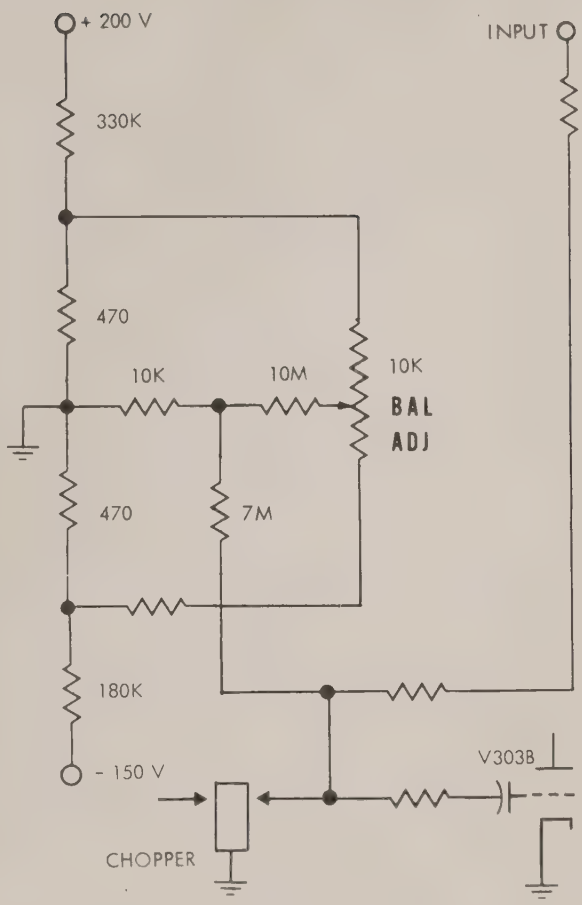


Figure 3-7. Balancing Circuit

Section IV
MAINTENANCE

4-1 INTRODUCTION

4-2. Maintenance information on the Model 111 Series Amplifiers includes the following:

a. Illustrations and text for identification of component parts,

b. General and detailed instructions for preventive maintenance of both amplifier and the cabinet enclosures,

c. Corrective maintenance instructions and data, and

d. Miscellaneous maintenance support data.

4-3. The detailed instructions given pertain to the Model 111BF and Model 111BFO Amplifiers. In virtually every case, these instructions are relevant to all the Model 111 Series Amplifiers -- exceptions are obvious or are specifically called out.

4-4 PART IDENTIFICATION

4-5. Component parts of the Model 111 Series Amplifiers may be identified from photographs on the following pages showing the amplifier from the top (Figure 4-1), from the underside (Figure 4-2), from the left side (and slightly under) (Figure 4-3), and from the right side (and slightly under) (Figure 4-4).

4-6. The majority of the smaller circuit parts -- resistors, capacitors, bias cells, and crystal diodes -- are mounted on three removable etched circuit boards. The photograph of the amplifier underside (Figure 4-2) shows the bottom edges of these three boards: one on the right side and two on the left. The front and rear left-hand boards are clear in the picture of the amplifier's left side (Figure 4-3), and the remaining board is shown in the photograph of the right side of the amplifier (Figure 4-4).

4-7. Identification of the small circuit parts for maintenance purposes is furthered by drawings of the circuit boards themselves, annotated with some voltages and with destinations of various circuit leads. Parts on the left front and left rear boards are identified from front to rear as viewed from the rear end of the chassis. Those on the right-hand board are called out from rear to front as viewed from the panel end of the chassis.

CAUTION

Extreme care must be used in handling the etched circuit boards. Salts and acids in the skin will contaminate the material, lowering the resistance between parts mounted on the boards. Clean cotton gloves are recommended for wear whenever the boards are to be touched for any reason.

4-8. Component parts of the Model 195 Cabinet and of the Model 190 Rack Module are easily identified. Most of the parts having any significance for maintenance are identifiable in Figure 1-7 for the Model 195 Cabinet and in Figures 2-3 and 2-4 for the Model 190 Rack Module.

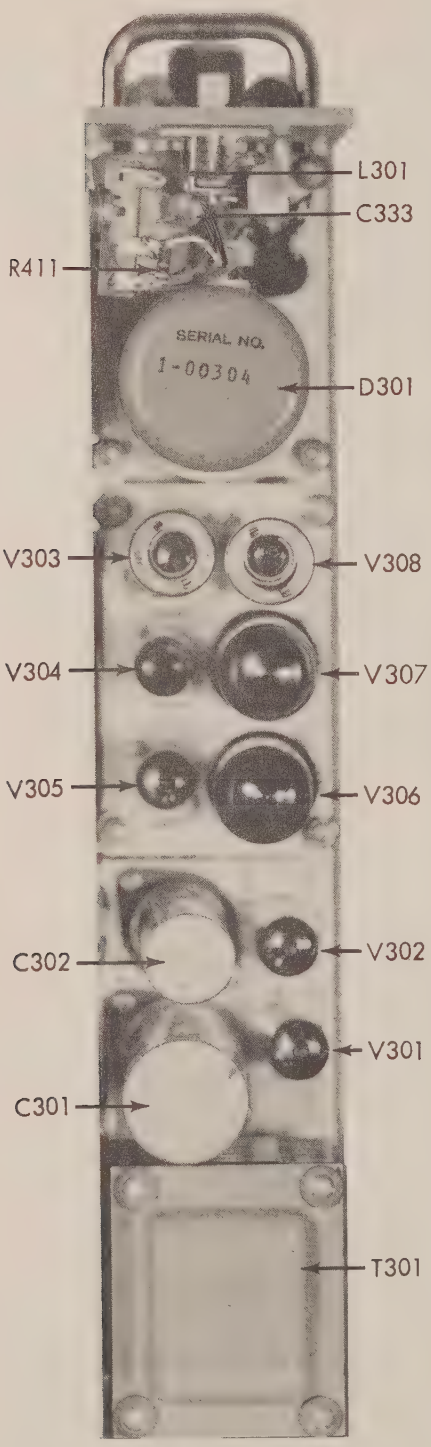


Figure 4-1. Top View of Model 111BF Amplifier

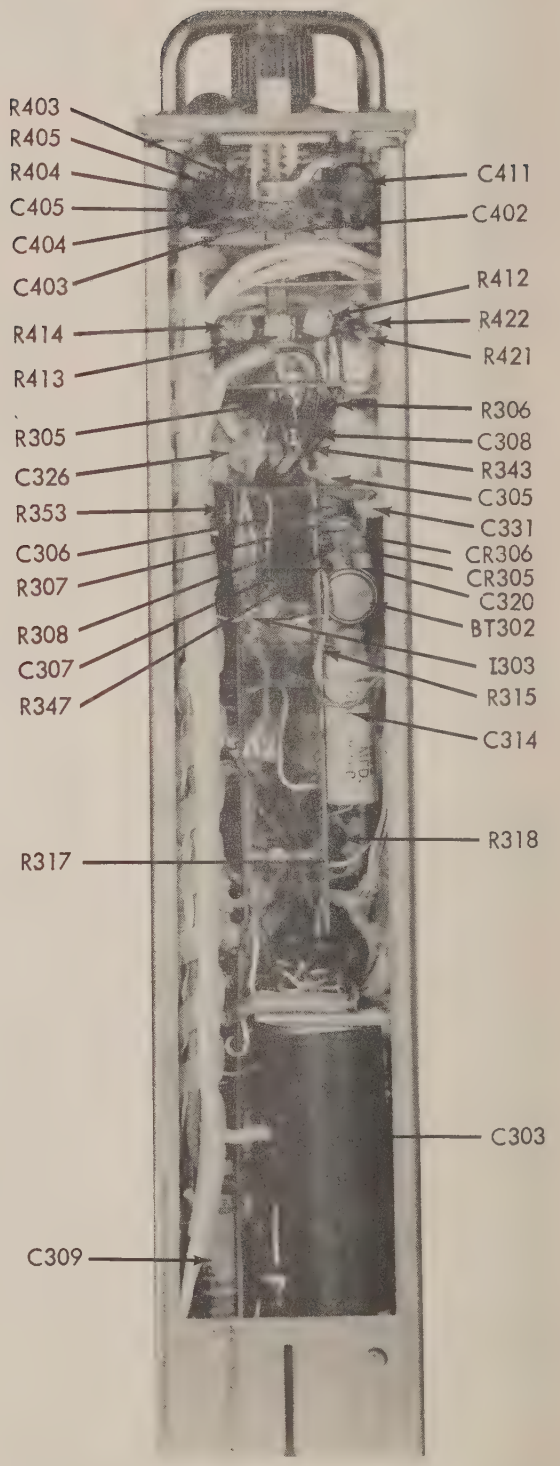


Figure 4-2. Bottom View of Model 111BF Amplifier

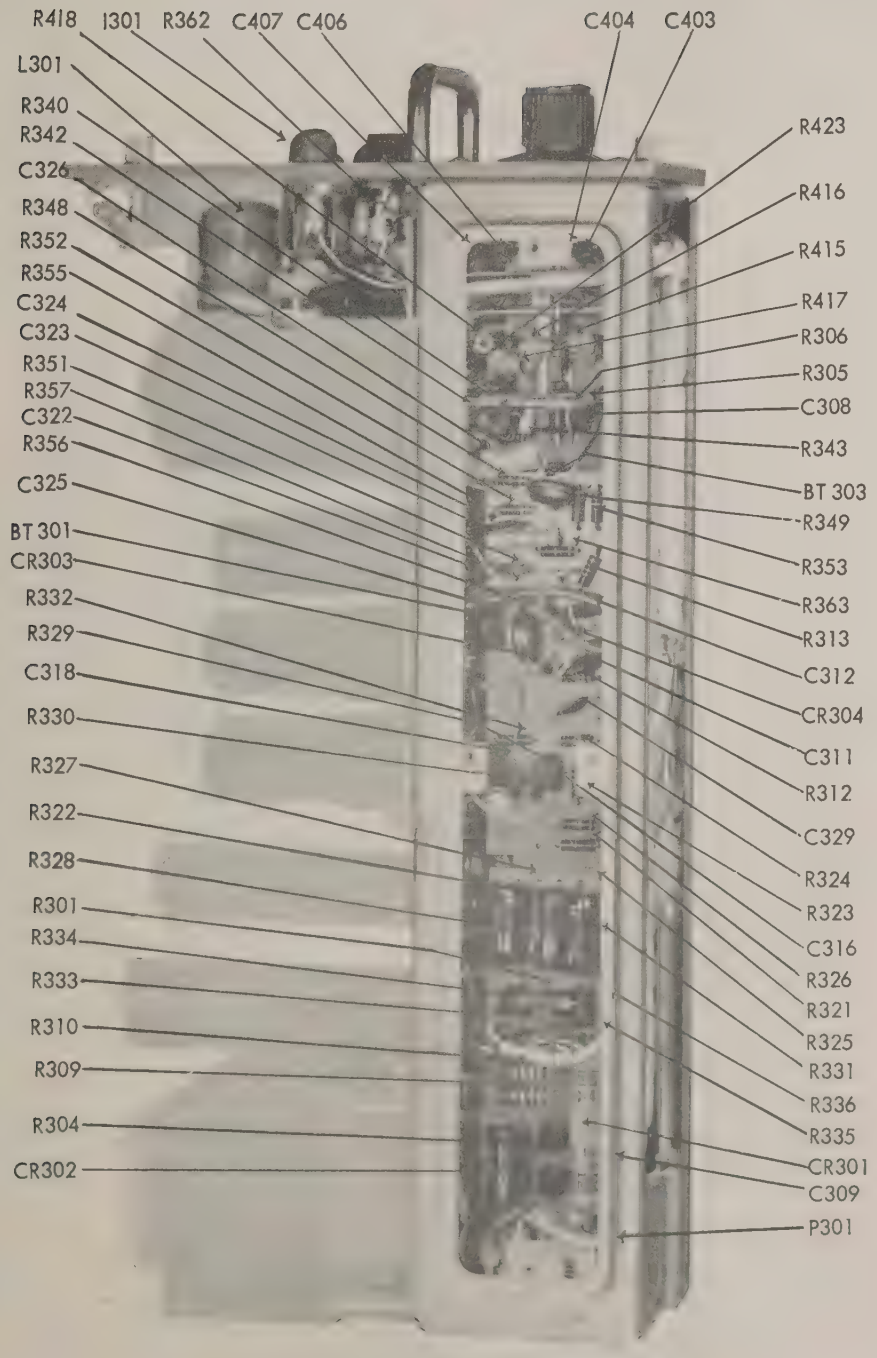


Figure 4-3. Left Side of Model 111BF Amplifier

4-9 PREVENTIVE MAINTENANCE

4-10. Preventive maintenance recommended for the Model 111 Series Amplifiers includes the following:

a. Initial check of DC voltages, resistances to ground, waveforms and signal levels,

b. Instructions for cleaning and lubricating,

c. Information to support simple checking of the chopper, tubes, and diodes, and

d. Brief directions for conducting each of various amplifier tests in-

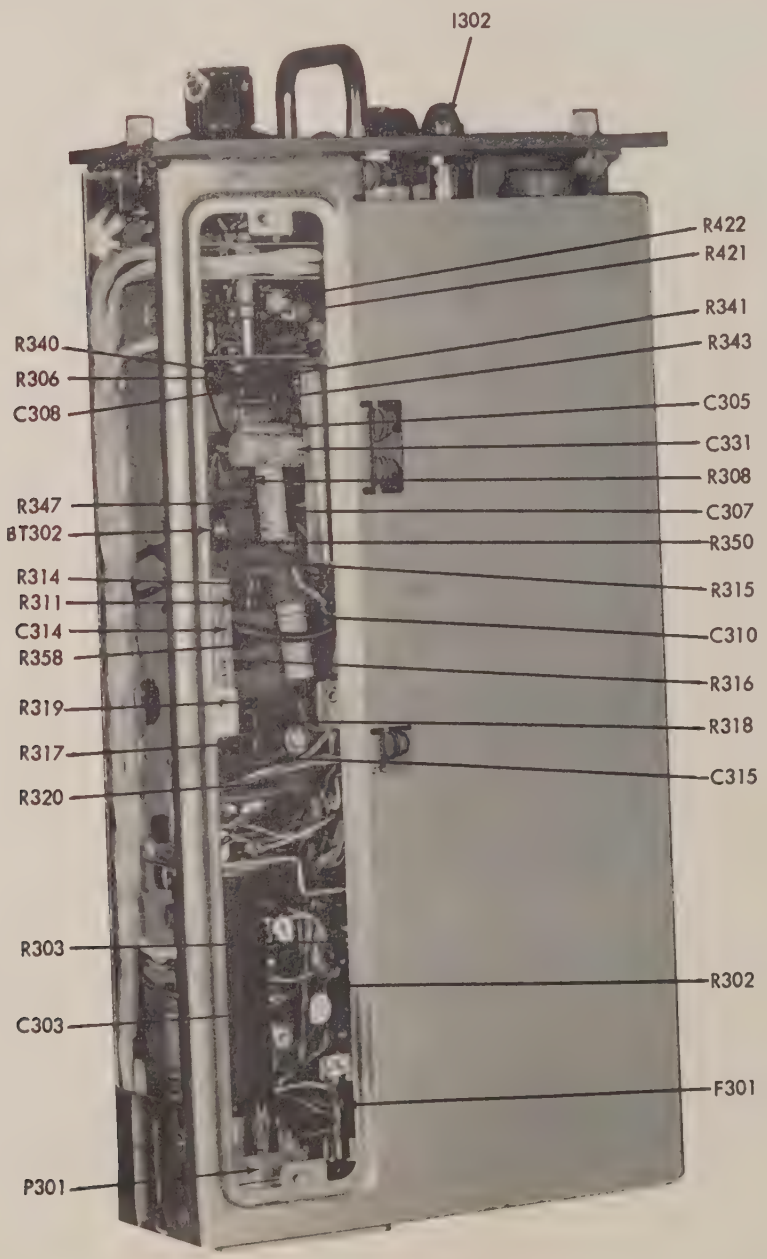


Figure 4-4. Right Side of Model 111BF Amplifier

volved in a comprehensive laboratory overhaul.

4-11. INITIAL CHECK OF VOLTAGES, RESISTANCES, AND WAVEFORMS. Maintenance support data included further in this manual contains tabulated readings of voltages and resistances to ground (refer to Tables 4-2 and 4-3), and shows waveforms and signal levels at various parts in the circuit. The individual bits of information are typical for the amplifier, and some mild variation may be encountered from unit to unit. An initial check should be made of these values of voltage and resistance, and any corrections should be noted on the tables in order to facilitate future corrective maintenance. Similarly, any discrepancies in waveforms and/or signal levels should be noted.

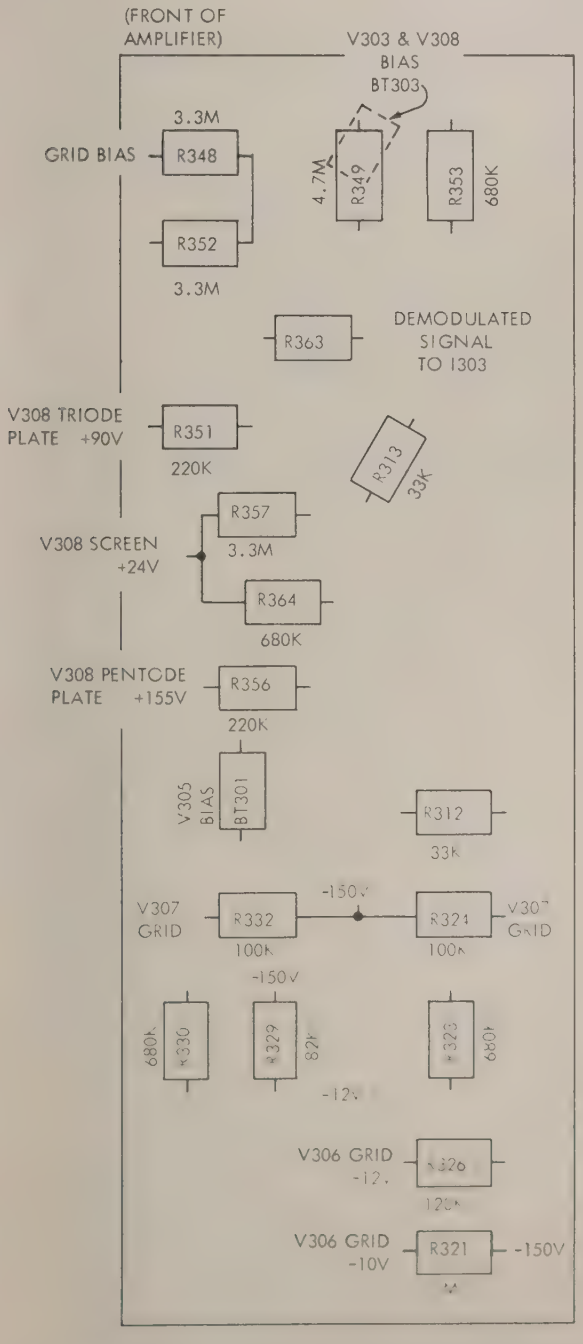


Figure 4-5. Left Front Circuit Board

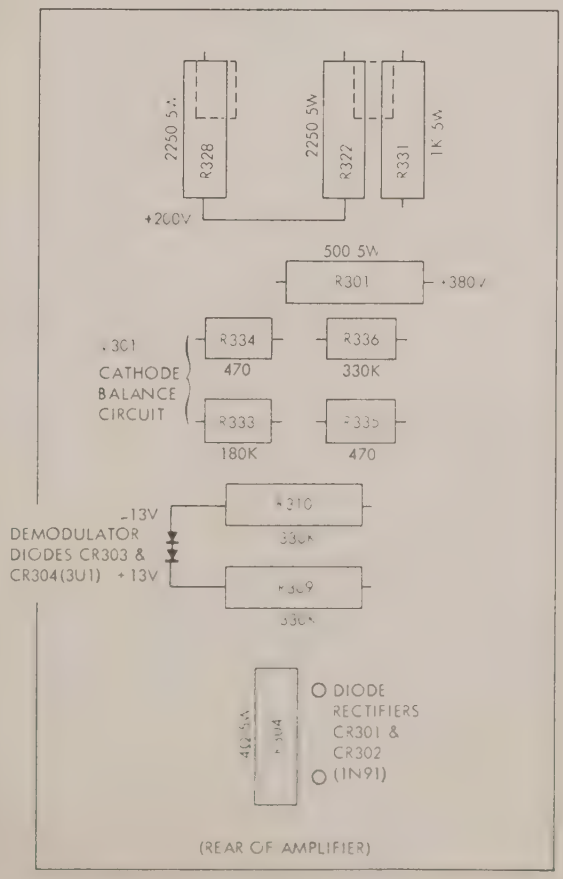


Figure 4-6. Left Rear Circuit Board

4-12. CLEANING. The Model 111 Series Amplifiers should be cleaned periodically -- the period being determined by the particular operating environment. The buildup of dust, dirt, and fluff at the sides and edges of the slots in the panel can serve as an indication of proper cleaning frequency. Dirt and dust will accumulate at the slots more rapidly than inside the amplifier. Similarly the upper part of the amplifier will require cleaning more frequently than the circuit elements beneath. Fluff can gather in some environments more rapidly than other kinds of dirt.

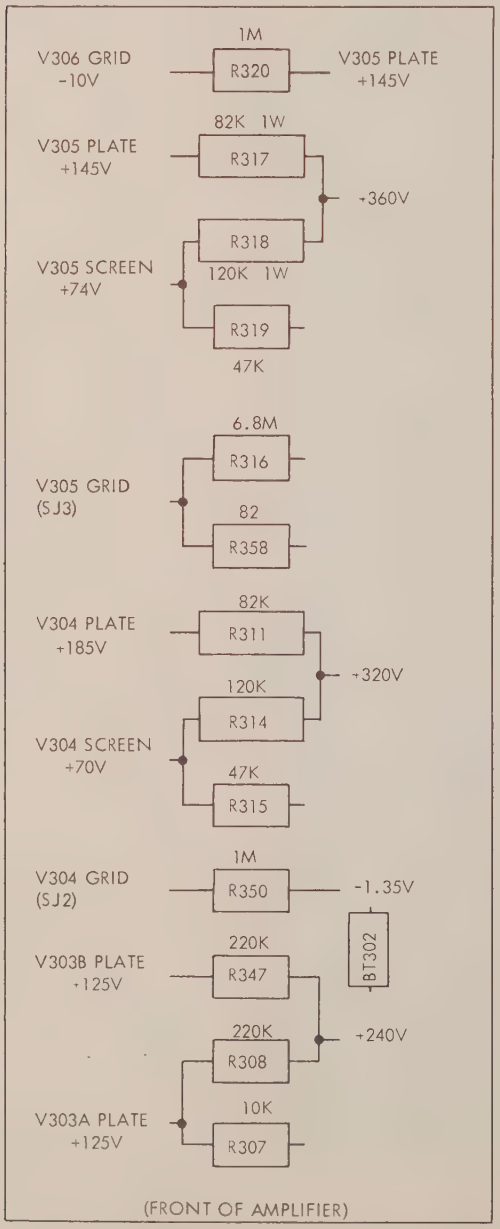


Figure 4-7. Right-Hand Circuit Board

4-13. Actually, the amplifier will function satisfactorily even when filthy. The harm from dirt and dust on top of the chassis is principally a matter of thermal insulation, and the accumulation must be extreme before cooling is seriously impeded. Fluff is another matter since this can impede the flow or air through the front slots.

4-14. Accumulation of dust, dirt, and fluff on the circuit boards is harmful, should be guarded against by periodic inspection and cleaning with a brush. Such accumulation occurs more readily when filler panels are used in a rack module than in a full cabinet.

4-15. The Model 195 Cabinet and the Model 190 Rack Module should be cleaned at roughly the same intervals as the amplifier. Accumulated dirt, dust, and fluff should be removed from around the fan openings and on the inner surfaces of a partially full rack module. The fan blades should be wiped down with a dry cloth. If cleaning is neglected until a large accumulation builds up on the fan blades, and if this deposit does not come off with a cloth, it should be removed by soaking the fan blades in solvent.

WARNING

Triclor and carbon tetrachloride give off toxic fumes. USE THESE SOLVENTS ONLY IN WELL VENTILATED AREAS.

4-16. LUBRICATION. No lubrication is required for the Model 111 Series

Amplifiers, but the fan motors used in both the Model 195 Cabinet and the Model 190 Rack Module must be lubricated after each 2000 hours of operation. Use Shell Oil No. 933, Code L-297, for the porous bearings on the fan motor shafts.

CAUTION

Do not use oils having a lacquer base. Improper oil will clog the porous bearing, coat it with a hard deposit, and impair the fan action.

4-17. If improper oils have been used on the fan motor(s), the following procedure will restore the coated bearings to their normal porosity.

a. Remove the motor assembly(ies) and disassemble. (See Figure 4-8.)

b. Scrape the bearing surfaces lightly to remove the hard deposit.

c. Soak the bearings in solvent for four hours or longer.

d. Remove deposit from shaft with a stiff brush dipped in the solvent.

e. Wipe the bearings thoroughly with a clean dry cloth to remove all deposit.

f. Soak the bearings in Shell Oil No. 933, Code L-297 for two hours or longer.

g. Wipe off excess oil. Reassemble the fan motor unit.

CAUTION

Align the motor shaft and bearings carefully before tightening the four frame bolts.

4-18. TUBE CHECKING. Vacuum tubes may be checked with a dynamic tube checker. The significant characteristic is the transconductance; note the transconductance values to assist in selecting replacement tubes. Such replacement cannot be made blindly; replacement tubes must give proper voltage/current relationships, hence must have acceptable transconductances. Any tubes discovered to have deteriorated somewhat through age should be operationally checked by voltage readings in the associated circuit. Tubes giving correct voltages in the surrounding circuit and working normally in the amplifier should not be discarded just because of tube checker indication.

4-19. DIODE CHECKING. Crystal diodes CR301 and CR302 may be checked in the circuit by measuring the 12-volt DC output across C302A. Diodes CR303 and CR304 may be checked in the circuit by measuring the +13 and -13 volts across them (Figure 4-6), also by checking the waveforms at the positive and negative junctions. (See

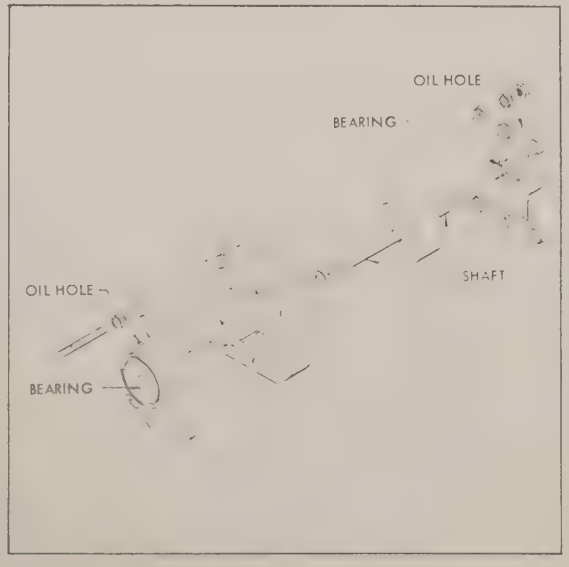


Figure 4-8. Exploded View of Fan Motor Assembly

Figure 4-9.) Crystal diodes CR305 and CR306 may be checked by substitution.

4-20. When one diode is suspected, it is good policy to replace both of a pair. If a single diode is open, characteristics will vary between a replacement and the remaining unit. Where a single diode is short-circuited, the remaining unit will likely have sustained some damage.

4-21. CHOPPER CHECKING. Some of the Model 111 Series Amplifiers use Brown (Minneapolis-Honeywell) choppers No. SS15374. Other units are equipped with KIN TEL choppers. Both operate identically and are interchangeable. Both receive the driving current from a connection on the side of the case. (See Figure 4-10.)

4-22. CHOPPER DIFFICULTIES. The difficulties associated with choppers are as follows:

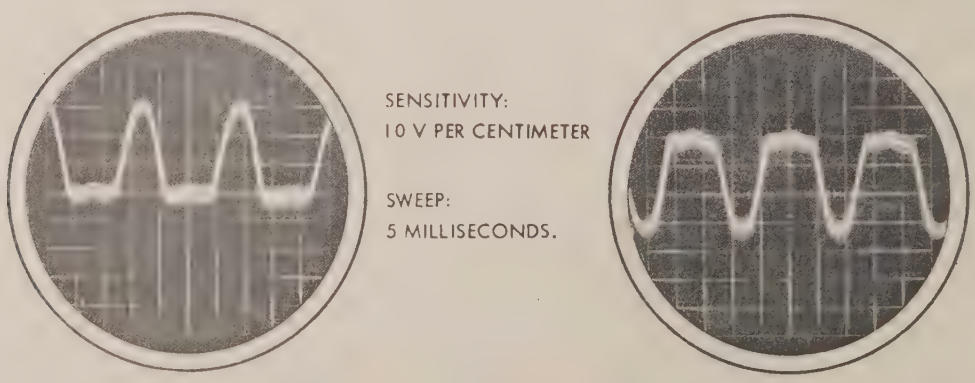
Inoperation,
Improper dwell time,
Sticky contacts,
Battery effect, and
Noise.

4-23. CHOPPER INFORMATION. Quality control in chopper manufacture has advanced to the point where complete nonoperation of a chopper is rare. A chopper that does not operate at all may be checked by touching the case with the hand. The vibration (or lack of it) is easily detectable.

4-24. CHOPPER DWELL TIME. Chopper dwell time may be checked by a bench setup involving a battery and (IMPORTANT) a current limiting resistor. (See Figure 4-10.) Dwell time of the other contact may be checked by connecting the negative lead from the battery to pin 5 instead of pin 3. Pin 4 is the make-before-break reed and should contact pins 5 and 3 approximately 55 percent of the time.

4-25. STICKY CHOPPER CONTACTS. The setup for checking dwell time also reveals any tendency toward contact stickiness. The waveform produced by a sticky chopper is erratic and will not synchronize with the oscilloscope sweep. Also the output from a Model 111 Series Amplifier having a sticky chopper will be unstable and rich in transients.

4-26. CHOPPER BATTERY EFFECT. Choppers have a considerable stack of reeds, guards, washers, solder tabs, and yokes in the base. (See Figure



POSITIVE JUNCTION NEGATIVE JUNCTION

Figure 4-9. Normal Waveforms at Demodulator

4-11.) In choppers that are not hermetically sealed, electrolysis within this stack of adjacent dissimilar materials occasionally produces the battery effect which is evidenced as offset, drift, or both. The offset can be compensated for by the ZERO ADJUSTMENT provided that

a. the amount of offset is stable (does not vary) and

b. the total offset is within the adjustment range.

4-27. The chopper specifications regarding battery effect state that there must be less than 5×10^{-12} volt per ohm of input circuit impedance generated by electro-chemical action between any combination of base pins. That voltage so generated is also specified to be stable within 10^{-12} volt per ohm of input circuit impedance. In the Model 111 Series Amplifiers, the input circuit impedance of 100K combines with this specification to assure that battery-effect offset be not greater than ±0.5 microvolt and be stable within ±0.1 microvolt. The Model 111 Amplifier specifications require drift to be less than ±2 microvolts equivalent input. With the amplifier in the 2000-times gain condition, allowable amplifier drift appears at the output as ±4 millivolts, chopper offset as ±0.001 volt.

4-28. Choppers showing excessive battery action (occasionally as much as 1200 microvolts) can sometimes be made to operate satisfactorily by heat treatment. Place the chopper in an oven at 50°C (122°F) for five to ten hours and recheck for battery effect. It may be necessary to repeat this treatment within a few months.

4-29. NOISE CHECK. Chopper noise is caused by improper chopper dwell time or by poor contacts within the chopper. Visually inspecting the output of the Model 111 Series Amplifier on an oscilloscope or a recording galvanometer will permit a check for the characteristic spikes of a noisy chopper. (See Figure 4-12.) The noise should not be ascribed to the chopper until a substitution of another chopper eliminates the noise.

4-30. CHOPPER REPLACEMENT. Choppers are installed in standard 6-contact sockets and have a small 2-pin connector at the side. Although this connector shows threads on the outer

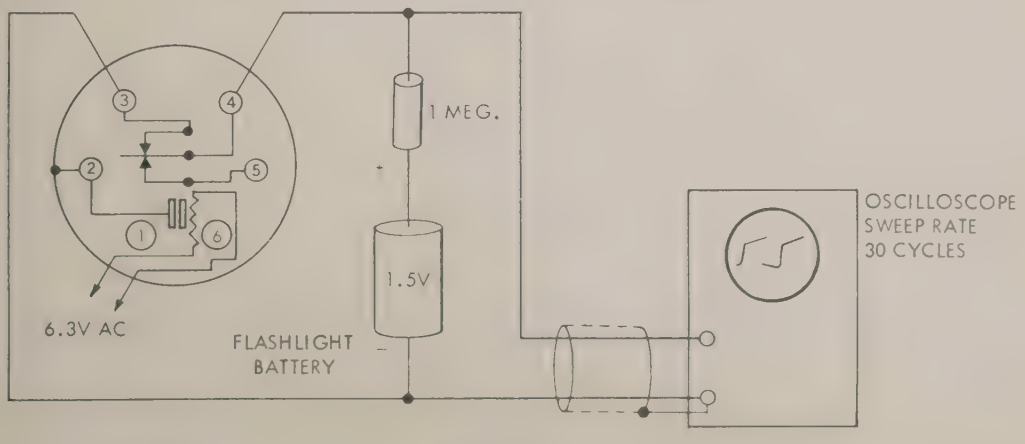


Figure 4-10. Bench Test Setup for Determining Chopper Dwell Time

surface of its housing, contact is made and broken by a straight push or pull. DO NOT ATTEMPT TO UNSCREW THIS CONNECTOR FROM THE SIDE OF THE CHOPPER. A straight pull with the fingers will disconnect the plug, after which the chopper may be removed from its socket by a straight upward pull. A clamp is situated to prevent accidental disconnection of the chopper and this clamp must be held back out of the way by a screwdriver while the chopper is gently rocked and pulled forward. The Brown and the KIN TEL choppers are interchangeable -- either may be used as a replacement for the other.

4-31. BIAS CELL CHECKING. Each Model 111 Series Amplifier uses three bias cells: BT301, BT302, and BT303. These cells may be small metalized discs, slightly larger blue lozenges with rounded edges, or still larger brown lozenges with squared-off edges. Two are located on the left front circuit board and one is on the right hand circuit board. (See Figures 4-5 and 4.7.) Each bias cell has a potential of 1.35 volts which lasts for the full shelf life of two years or longer, deteriorates very quickly after the voltage begins to fall. This voltage may be checked by a vacuum tube voltmeter directly across the cell -- NOT from ground to high side. Replace the cell if the reading is 1.2 volts or lower. The replacement procedure is as follows:

a. Place the Model 111 Series Amplifier on the bench. Identify the bias cell to be replaced.

b. Use a small iron with a bent tip to apply heat to the underside of the board at the cell, removing solder and shaking it from the iron until the cell leads are sufficiently clean.

c. Straighten the ends of the bias cell leads and withdraw the cell.

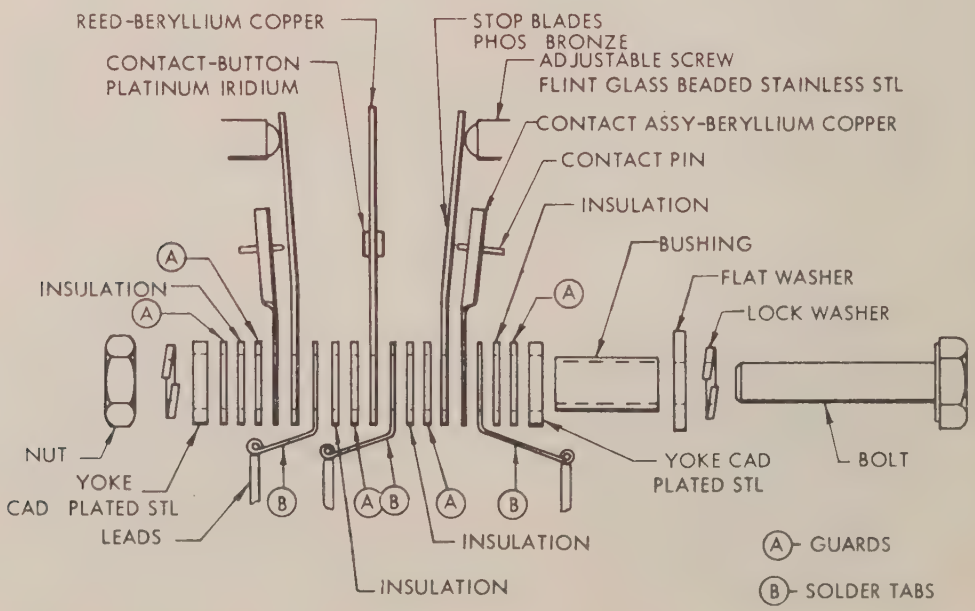


Figure 4-11. Chopper Stack, Exploded

d. Insert the leads of the replacement cell; bend the leads outward and clip them off close to the board but within the curve so that the short bent leads hold the cell in place mechanically. Apply solder sparingly for electrical contact.

4-32. BENCH OVERHAUL. For optimum usage, each Model 111 Series Amplifier should be checked in more formal tests -- static and dynamic -- after each 1000 hours of operation. These tests should take the fullest advantage of the available amplifier-testing facilities of the laboratory. Individual tests are briefly described in the following paragraphs. The test results should be logged and maintained to serve as a basis for subsequent corrective maintenance as needed. Recommended test data sheets are included here. (See Figures 4-13 and 4-14.)

4-33. EQUIPMENT NEEDED. The test equipment needed for a full-dress bench overhaul of a Model 111 Series Amplifier is as follows:

Multimeter: Hewlett-Packard Model 410B or equivalent (for static testing)

Test Bridge: KIN TEL Model 110T

AC Vacuum Tube Voltmeter: Hewlett-Packard Model 400D or equivalent (0.001 to 300 volts)

Oscilloscope: Hewlett-Packard Model 130A or equivalent (0.1 mv/cm sensitivity)

Microvoltmeter-Amplifier: KIN TEL Model 202B or 203

Recorder: Esterline-Angus Model AW or equivalent

Audio Oscillator: Hewlett-Packard Model 201C or equivalent

±2% AC Voltage Source: Sorenson Regulator Model 1000S or equivalent -- also General Radio Variac Model W5MT or equivalent. (For line voltage noise tests, a 0.4-ohm 5-watt resistor may be inserted into the AC line.)

NOTE

The Model 111TC Test Cable is NOT used in a bench overhaul. This unit is for use with the amplifiers removed from their customary housing, hence with altered electrostatic shielding and ventilation. This cable is used in corrective maintenance only.

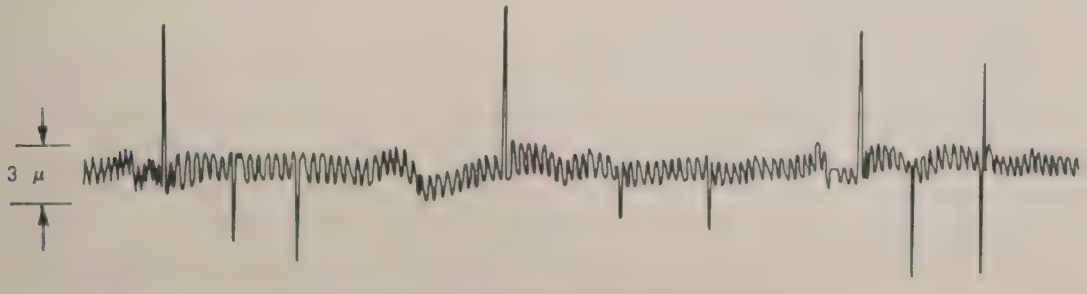


Figure 4-12. Chopper Noise Spikes in Model 111 Amplifier Output

4-34. The KIN TEL Model 110T Test Bridge was specially designed for testing the Model 111 Series Amplifiers. It provides proper loading, bandpass filters, and a means for analyzing intermodulation and phase distortion. The attenuators in this bridge are extremely accurate and provide a check on the Model 111 attenuators. (See Figure 4-15).

4-35. The KIN TEL Model 202B and Model 203 are microvoltmeters and amplifiers having very high input impedance, very low drift, and gains of 70 and 80 db respectively. One of these is used in the drift and balance test setup. (See Figure 4-16.)

4-36. Where a number of Model 111 Series Amplifiers are to be tested, it is convenient to connect one amplifier enclosure as a test bridge module (Figure 4-15) and another as a drift test module (Figure 4-16). Amplifiers may then be inserted in the bridge module for all noise and gain testing, and put into the drift module for all drift and balance tests.

4-37. TEST CONDITIONS. The following conditions are valid for the tests:

a. Temperature: Conduct all tests at the normal operating temperature for the amplifiers in their existing installation.

b. Line voltage: Line voltage tests require the 60-cps line to be changed in 1-volt steps. Noise and drift tests require a change of ±10 percent (11.7 volts).

c. Loading: The amplifiers are to operate into 1000 ohms except where stipulated otherwise.

TEST DATA SHEET

DATE_____ SERIAL NO._____ CHECKED BY_____

	FROM PIN	TO	OHMMETER READING, OHMS	(SHOULD BE)
	1	2,5,7,11		ZERO
	1	4,6,8,10		OPEN
1. All Units:	4	all terminals		OPEN
Gain Switch	4	chassis		SHORT
20 or Above	3	9		SHORT
	3	1		9K
	8	10		APPROX 5
	11	12		500 K
	1	9		9K
2. Non-operational	1	9		SHORT
Units. Gain	3	9		9K
Switch at Zero	(all others as per gain switch 20 or above)			
3. Operational	11	12		780 K
Units. Gain	(all others as per gain switch 20 or above)			
Switch at Zero				

Figure 4-13. Data Log Sheet for Static Tests

DATE _____ SERIAL NO. _____ CHECKED BY _____

		(SHOULD BE)
1.	50 KC NOISE TEST (RMS):	
	X1000 _____ X700 _____ X500 _____ X300 _____ X200 _____	≤12 μv EQ. IN
	X100 _____ X70 _____ X50 _____ X30 _____ X20 _____	
2.	750-CYCLE NOISE TEST (RMS): X1000 _____	≤5 μv EQ. IN
3.	3-CYCLE NOISE TEST (P-P): X1000 _____	≤5 μv EQ IN
4.	GAIN ACCURACY TESTS (2 KC IN, 1000 Ω LOAD):	
	X1000 _____ X700 _____ X500 _____ X300 _____ X200 _____	≤1%
	_____ _____ _____ _____ _____	
	_____ _____ _____ _____ _____	
	X100 _____ X70 _____ X50 _____ X30 _____ X20 _____	
	_____ _____ _____ _____ _____	
	_____ _____ _____ _____ _____	
	(2 KC IN, 100 Ω LOAD): X1000 _____	
	_____	≤1%
	_____	
	(10 KC IN, 1000 Ω LOAD):	
	X1000 _____ X700 _____ X500 _____	
	_____ _____ _____	
	_____ _____ _____	≤5%
	X300 _____ X200 _____ X100 _____	
	_____ _____ _____	
	_____ _____ _____	
5.	LINEARITY TESTS (2 KC IN, 1000 Ω LOAD): X1000 _____ X2[illegible] _____	≤0.1%
	(2 KC IN, 100 Ω LOAD): X1000 _____	≤0.1%
6.	OVERLOAD RECOVERY TEST: _____ SECONDS	≤3 SECONDS
7.	CHOPPER INTERMODULATION TEST: X1000 _____	≤0.1%
8.	BALANCE TEST: _____ MV _____ MV TOTAL SWING _____ MV	60-90 MV TOTAL
9.	DRIFT TESTS: ± _____ μv EQUIVALENT INPUT	≤±2 μv

Figure 4-14. Data Log Sheet for Dynamic Tests

d. Gain: Amplifier gain is to be set at 1000 except where stipulated otherwise. Gain setting of the testbridge must correspond to that of the amplifier.

e. Input: Short-circuit the amplifier input at all times that no stipulated signal is being applied.

f. Balance: The BALANCE control must be adjusted for zero output with short-circuited input before conducting any tests.

4-38. STATIC TESTING. Disconnect the amplifier from the AC line and use the multimeter to measure the resistance between terminals of the amplifier connector (Cannon plug). Log the readings. (See Figure 4-13.)

4-39. DYNAMIC TESTING. Dynamic tests are described individually below in roughly the order of logging them on the dynamic test chart (Figure 4-14). Some tests are described that are not called out on the test chart but which should be performed. The initial tests (noise tests) require either a test bridge module or a test setup involving the Model 110T bridge. (See Figure 4-17.) Subsequent tests involve modifying the test setup. (See Figures 4-18 and 4-19.)

4-40. NOISE TEST -- 50 KC (RMS). Wideband noise is measured with the OUTPUT FILTER switch of the test bridge at 50 kc, shorting the amplifier input by setting the test bridge GAIN switch to zero at which point it remains throughout all noise tests. The FILTER OUT switch must be in the ON position. Take VTVM readings in all amplifier gain ranges with vernier gain potentiometer fully CCW and repeat on the x1000 and x20 gain ranges with pot fully CW. The noise level reading in all cases shall be less than 12 microvolts (rms) of equivalent input.

4-41. NOISE TEST -- 750 CPS (RMS). Noise in the spectrum DC to 750 is measured by setting the OUTPUT FILTER switch of the test bridge to 750 cps. Other settings remain the same as in the 50 kc Noise Test. VTVM readings are taken in the x1000 gain settings with vernier gain pot fully CCW and repeated with pot fully CW.

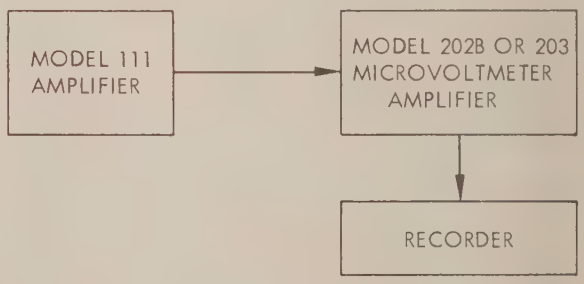


Figure 4-16. Drift Test Module Connections

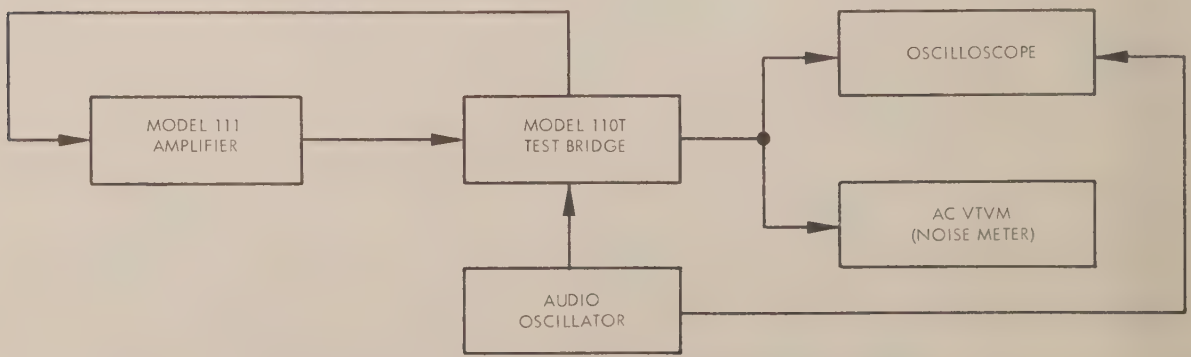


Figure 4-15. Test Bridge Module Connections

Noise level readings shall be less than 5 microvolts (rms) of equivalent input.

4-42. NOISE TEST -- 3 CPS (P-P). Noise in the spectrum DC to 3 cps is measured by setting the OUTPUT FILTER switch of the test bridge to 3 cps. In this test, the recommended oscilloscope is used as the indicating instrument. For this test ONLY, the vertical input leads of the scope are to be connected to the FILTER OUTPUT terminals of the test bridge. The noise level reading shall be less than 5 microvolts (peak-to-peak) of equivalent input. This test is performed with an amplifier gain setting of x1000 and with the vernier gain control in the maximum counterclockwise position. Log results.

4-43. LINE VOLTAGE NOISE TEST. With the amplifier input short-circuited, change the AC line level suddenly by 1 volt rms -- either by variac or by inserting a 0.4-ohm 5-watt resistor in the AC line. Deflection on the oscilloscope should not exceed 5 microvolts (peak-to-peak) of equivalent input.

4-44. GAIN ACCURACY TESTS. For performing the gain accuracy tests, alter the test setup to include an oscillator for furnishing signals to the bridge external input and to the oscilloscope horizontal input. (See Figure 4-18.)

4-45. Apply an audio signal of 2 kc 15 volts rms to the bridge (and oscilloscope). Measure gain on each gain range of the amplifier, adjusting the test bridge GAIN switch to correspond with that of the amplifier.

4-46. Adjust the PHASE dial of the test bridge to obtain the narrowest pattern on the oscilloscope. Adjust the GAIN ERROR dial to align the pattern horizontally with the X-axis of the oscilloscope. Convert both dial readings to percentages by means of the charts

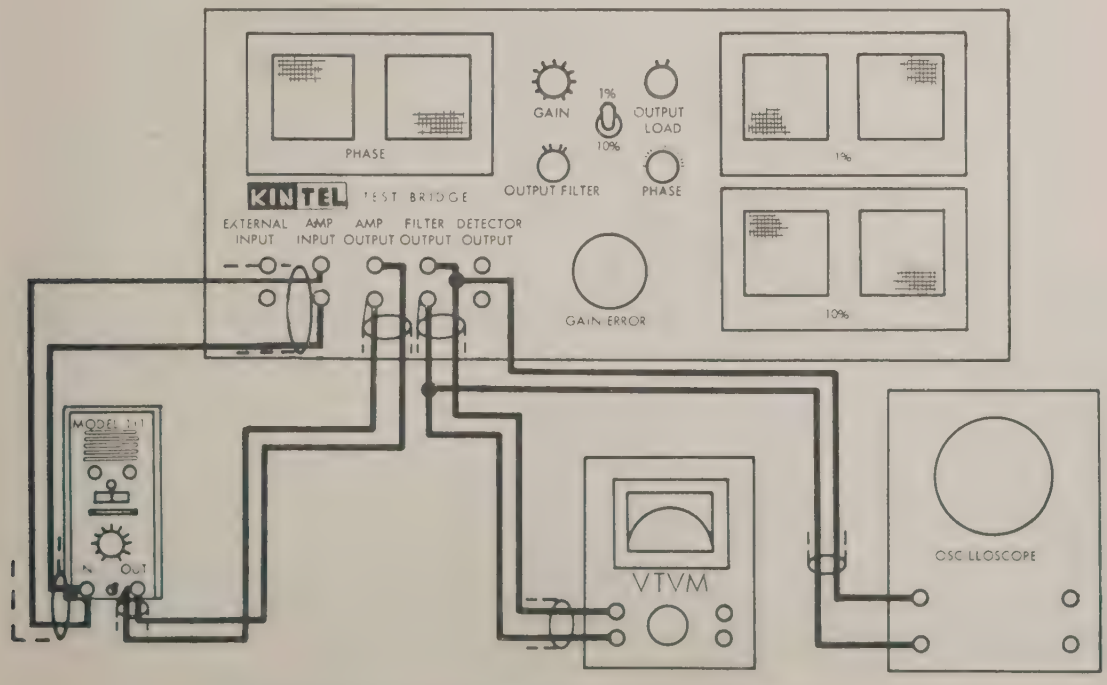


Figure 4-17. Setup for Noise Tests

on the test bridge panel. Gain error and phase error must be added algebraically to obtain the composite gain error. (Phase readings are negative; GAIN ERROR dial position determines the sign of the gain error -- positive if to the right of the zero, negative if to the left). The total is a true gain error and must not exceed ±1 percent. Note that the 1-percent position of the switch and the 1-percent chart should be used where possible; if not possible, then the 10-percent position and the 10-percent chart should be used. (This is valid only for the 2 kc signal -- a different chart is used for a 10 kc signal.)

4-47. Set the OUTPUT LOAD switch to the 100 position, and reduce the output from the audio oscillator to approximately 1.5 volts rms as read on the vacuum tube voltmeter. Make gain measurements with the amplifier and test bridge gain settings of x1000. (The amplifier VERNIER GAIN control must be set to the maximum counterclockwise position.) Composite gain error must not exceed ±1 percent.

4-48. Reset the audio oscillator to 10 kc, adjust the audio output to 15 volts rms, and reset the OUTPUT LOAD switch to the 1000 position. Make gain measurements on each range as in the previous tests. The composite gain error must not exceed ±3 percent.

4-49. At this point a check may be made to determine the actual gain as related to the setting of the VERNIER GAIN control. Set the amplifier and test bridge gains to x500 and have the VERNIER GAIN control fully counterclockwise. Note the composite gain error reading at this point. Now reset the VERNIER GAIN to the maximum clockwise position and change the test

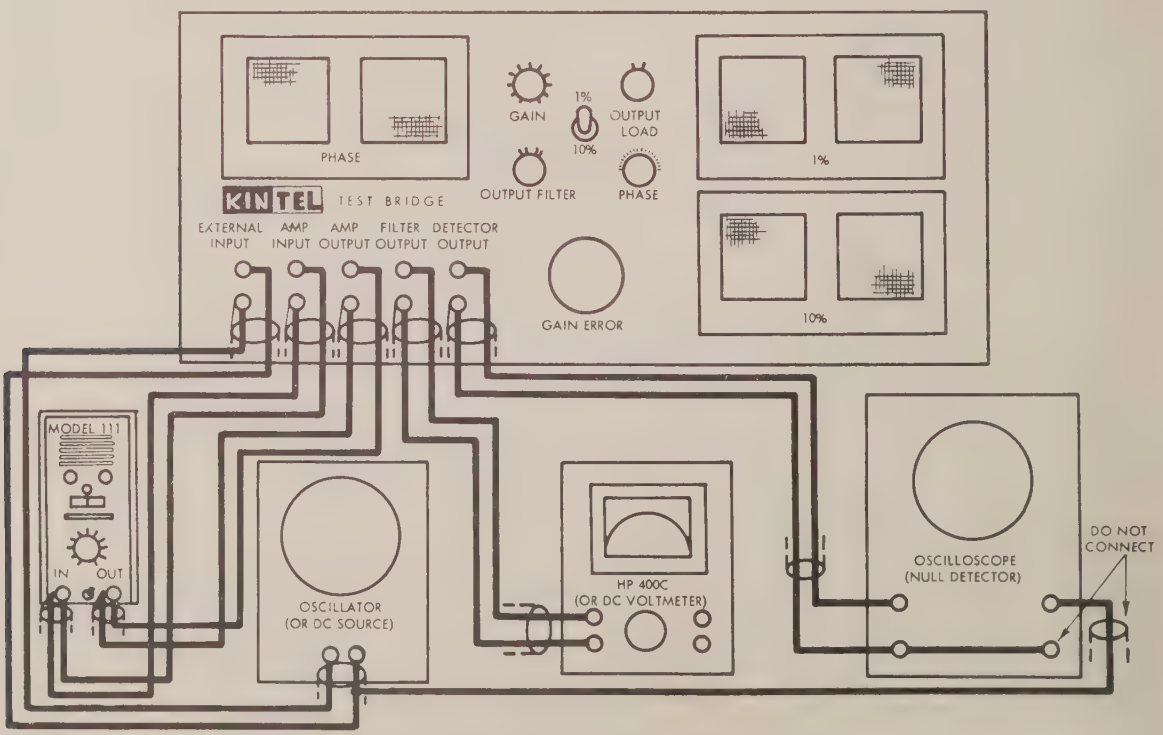


Figure 4-18. Setup for Gain Accuracy Tests

bridge gain setting to x1000. The resultant reading should be greater than twice the reading obtained with the VERNIER GAIN control in the counter-clockwise position.

4-50. LINEARITY TEST -- 1000-OHM LOAD. For the linearity tests, connect the vacuum tube voltmeter and the oscilloscope vertical input to the EXTERNAL INPUT of the test bridge (to the oscillator). (See Figure 4-19.) Switch the bridge OUTPUT LOAD to 1000 ohms. Adjust the audio output from the oscillator to 25 volts rms as indicated by the vacuum tube voltmeter. With the oscilloscope horizontal gain at zero, adjust the vertical gain for full scale deflection with this signal.

4-51. Move the leads to the vertical oscilloscope input and the vacuum tube voltmeter to the amplifier output terminals. The waveform on the oscilloscope should change only by phase reversal.

4-52. Now move the oscilloscope vertical input leads to the bridge DETECTOR OUTPUT terminals. (Leave the vacuum tube voltmeter connected to the amplifier output.) Increase the oscilloscope vertical sensitivity by 100, and set the horizontal gain for full X-axis deflection. Because only half of the signal appears at the bridge DETECTOR OUTPUT, the oscilloscope will read 2 percent full scale instead of 1 percent.

4-53. Now adjust the bridge PHASE and GAIN ERROR dials for a null indication. (See Figure 4-20.) The resulting oscilloscope pattern should be no higher than that shown -- roughly 0.25 centimeter.

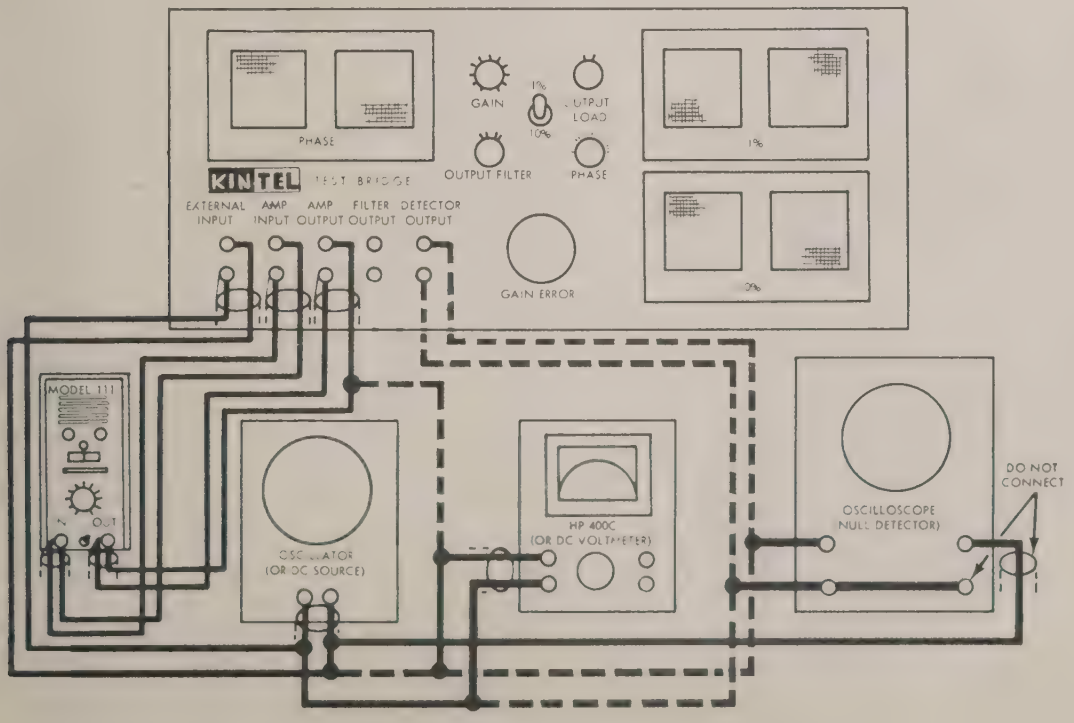


Figure 4-19. Setup for Linearity Tests

4-54. Increase the output level of the audio oscillator slowly until the outer envelope of the signal displays a distortion of 0.5 centimeter on the oscilloscope scale. The increasing voltage will have no evident effect until some particular level when the distortion will begin to appear and will increase rapidly. The level at which distortion reaches 0.5 centimeter is usually about 27 volts. (See Figure 4-21.) If the signal is then decreased slowly, the downward hook at the right -- the distortion -- disappears into the outer envelope at approximately 26.5 volts.

4-55. The amplifier output is 180 degrees out of phase with the input, and the fundamental frequencies as they appear at the DETECTOR OUTPUT terminals are canceled. The resulting signal is therefore an indication of the peak-to-peak nonlinearity of the amplifier.*

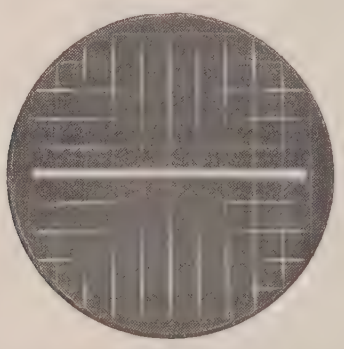


Figure 4-20. Normal Linearity

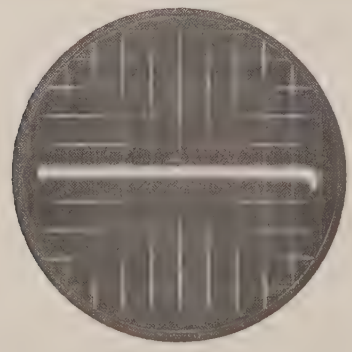


Figure 4-21. Nonlinearity Indication

NOTE

This measurement is valid only if the audio oscillator output level remains unchanged after calibrating the oscilloscope.

4-56. Perform this test with the amplifier gain set at x20 and x1000. Keep the VERNIER GAIN control fully counterclockwise. Maintain the amplifier output at 25 volts rms. Log the output levels required for distortion.

4-57. LINEARITY TEST -- 100-OHM LOAD. Connect the oscilloscope vertical input leads and the vacuum tube voltmeter leads to the EXTERNAL INPUT terminals. (See Figure 4-19.) Change the bridge OUTPUT LOAD switch to 100 ohms. Set the audio oscillator output level to 2.8 volts rms as read by the vacuum tube voltmeter. Turn the oscilloscope horizontal gain to zero and adjust the vertical gain for full scale deflection with this signal applied.

4-58. Remove the vacuum tube voltmeter and oscilloscope vertical input leads from EXTERNAL INPUT to the AMPLIFIER OUTPUT terminals on the bridge so that the waveform may be compared with that at the EXTERNAL INPUT terminals. The waveform should be identical except for a reversal of phase. Now move the oscilloscope vertical input leads to the DETECTOR OUTPUT, increase the oscilloscope vertical sensitivity by 100, and set the oscilloscope horizontal gain for full scale deflection. The oscilloscope now indicates 2 percent nonlinearity at full scale because of the factor of two introduced by the test bridge. Refer to paragraph 4-52.

*Linearity specifications of the Model 111BF Amplifier are stipulated "better than 0.1 percent to 2 KC at full output" --- peak AC output is rated at 35 volts with a 1000-ohm load. The 25-volt signal used in linearity testing is 35 volts peak.

4-59. Adjust the PHASE and GAIN ERROR dials for a null and measure the distortion of the envelope on the oscilloscope. The amplifier is within specification if the nonlinearity does not exceed 0.1 percent. (See Figure 4-20.) The amplifier output must be maintained at 2.8 volts rms to assure validity.

4-60. OVERLOAD RECOVERY TEST. Adjust the audio oscillator for 2 kc, 10 volts rms. Put the bridge OUTPUT LOAD switch in the 1000-ohm position, and set both amplifier and bridge gains at x1000. Switch the test bridge GAIN control suddenly to x100 for approximately 3 seconds, and time the moment at which GAIN is switched back to x1000. The oscilloscope pattern should return to normal within 3 seconds (or less) after the GAIN was switched to x1000.

4-61. Repeat the above test with a 1-microfarad capacitor across the amplifier output terminals. Again the amplifier should recover from overload within 3 seconds or less.

4-62. Move the GAIN controls of both amplifier and bridge to x100 and then switch the test bridge GAIN suddenly to x20 for 3 seconds. Time the moment of switching back to x100. Less than 3 seconds should be required for the oscilloscope pattern to return to its normal display.

4-63. Remove the 1-microfarad capacitor and repeat the above test. Again the amplifier should recover from overload within 3 seconds.

4-64. CHOPPER INTERMODULATION TEST. Move the vacuum tube voltmeter leads and the oscilloscope vertical input leads to the EXTERNAL INPUT terminals. (See Figure 4-19.) Switch the bridge OUTPUT LOAD to the 1000-ohm position. Set amplifier and bridge GAIN controls to x1000. (VERNIER GAIN control must be fully counterclockwise.) Adjust the audio oscillator for 60 cps, 10 volts rms as indicated by the vacuum tube voltmeter. Calibrate the oscilloscope as indicated in paragraphs 4-51 and 4-52.

4-65. Waveform movement is so slight that close observation is needed to detect any deviation. Measurement of this deviation is not a peak-to-peak determination, but rather a notation of departure from the norm as referenced to a given peak. (See Figure 4-21.) If this deviation appears to be less than 0.1 percent (0.5 centimeter on the oscilloscope), the chopper intermodulation is within specification. Typical intermodulation is of the order of 0.03 percent.

4-66. BALANCE TEST. Use the drift module for this test. Otherwise, connect the microvoltmeter to the amplifier output. Set the amplifier GAIN to x1000, and short-circuit the amplifier input. (Do not connect anything to the bridge EXTERNAL INPUT terminals.) Rotate the amplifier BALANCE control over its complete range while observing the microvoltmeter indication. The total swing caused by this rotation should be between 60 and 90 millivolts. When the microvoltmeter registers zero, the BALANCE control should be in the center of its range. Reset the microvoltmeter range switch to the 10-microvolt position and adjust the BALANCE control for zero indication on the microvoltmeter.

4-67. DRIFT AND SHOCK TESTS. Use the drift module. Otherwise, connect as for the balance test but feed the

microvoltmeter output to the recorder. Record each amplifier output for 15 minutes, and evaluate the recording for drift which should not exceed ±2 microvolt referred to the shorted amplifier input. The amplifier should be tested also for sensitivity to shock by striking the module sharply with the hand. After an initial offset, the recording should show an immediate return to its previous stable position.

4-68. TESTING WITHOUT A BRIDGE. Where the amplifier installation is not extensive enough to warrant purchase of a Model 110T Test Bridge, the individual amplifiers should be tested by use of standard laboratory equipment. Not all the tests described above can readily be conducted with the equipment customarily found in electronic laboratories. In most cases, however, sufficient tests can be performed to assure continued satisfactory amplifier operation.

4-69. Noise tests may be conducted in the wideband condition without difficulty. The band may be narrowed to 750 cps by a simple RC filter for further testing. (See Figure 4-22.) The band may be further narrowed to 3 cps by substituting a 56K resistor and a 1.0 microfarad capacitor for the values shown in the illustration. Measurement of 3-cycle noise may be done on the oscilloscope -- the vacuum tube voltmeter is not sufficiently sensitive to show the normal noise in this band.

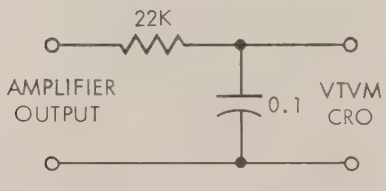


Figure 4-22. 750-Cycle Filter

4-70. Gain accuracy tests require external attenuators of extremely high precision in order to assure validity. Absolute accuracy of the individual resistors must be within 0.01 percent and the relative accuracy between individual resistors in a divider must be within 0.005 percent. (See Figures 4-23 and 4-24 for configurations of dividers and test setup.)

4-71 CORRECTIVE MAINTENANCE

4-72. Corrective maintenance consists of detecting circuit malfunctions, localizing the difficulty, diagnosing the trouble, and repairing the amplifier.

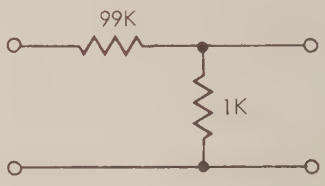


Figure 4-23. Precision 40-db Attenuator

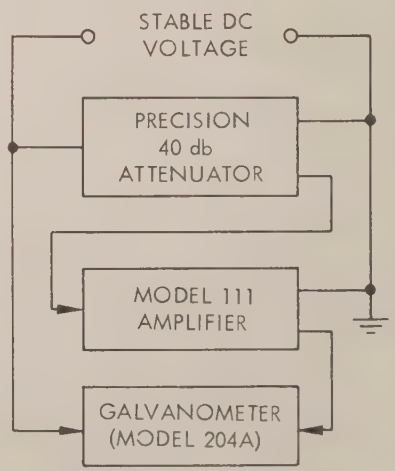


Figure 4-24. X100 Gain Test

Corrective maintenance instructions and information consist of a general discussion of troubleshooting techniques for the amplifier, referring to data included later in the manual, followed by more specific discrete operating difficulties and corresponding circuit flaws -- many listed in a table.

4-73. GENERAL. As a general maintenance procedure, a malfunctioning or inoperative Model 111 Series Amplifier should be checked first for leakage resistance between signal ground and chassis -- this resistance should be 50 megohms or more and is typically several hundred megohms. Following this, the bias cell voltages should be checked. Only after leakage to ground and bias are found to be normal should the amplifier be plugged into the AC line.

4-74. A Model 111TC Test Cable is a useful aid to troubleshooting the amplifier since it permits operation on the bench. (See Figure 4-25.) Operating the amplifier with this test cable will give noisy output signals because of the fields on the test bench.

4-75. DIAGNOSIS. Diagnosis of the operating difficulty is complex because of the amplifier feedback. Individual circuit flaws are reflected back and appear throughout the amplifier. Maintenance support data furnished later in this manual include tabulated readings of voltage and resistance to ground in normal operation. (Refer to Tables 4-2 and 4-3.) Any discrepancy from the listed values indicates an anomaly, but in many cases a single malfunction will appear as numerous discrepancies so that a troubleshooting path is out-

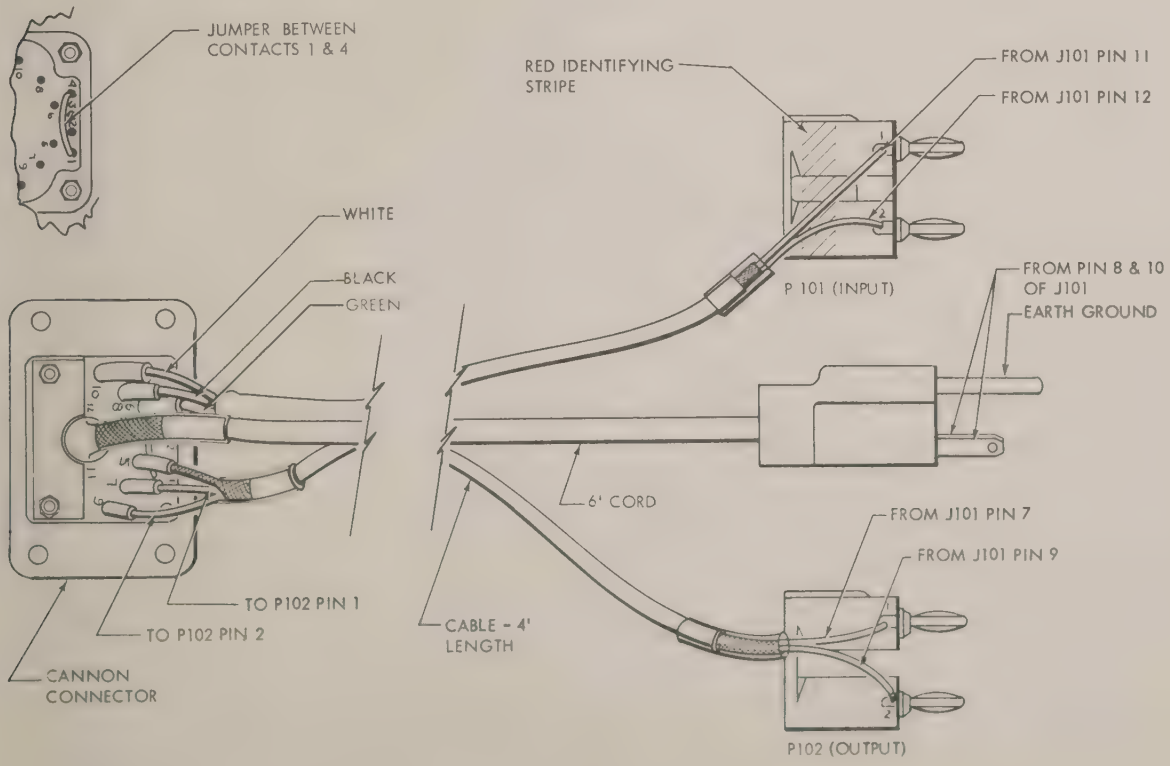


Figure 4-25. Model 111TC Test Cable

Table 4-1. Troubleshooting Guide

OPERATING DIFFICULTY	PROBABLE CAUSE
Drift	Defective chopper
	Leaky C305, input capacitor
Inaccurate gain	Leaky C320, coupling capacitor
	Attenuator resistor, R412 to R423, changed value
	Input resistance, R305 and/or R306, changed value
Gain error at 10 KC (gain normal at 2 KC)	Defective capacitor in capacitive deck of feedback attenuator, C401 to C411
Gain greatly in excess of normal -- unstable output	No feedback; attenuator or leads open
Slight nonlinearity	Output bridge tubes, V306 and V307, defective
-- on Model 111A	Bridge capacitor, C317 (this capacitor has been deleted in later models)
3-cps noise out of spec	Defective chopper
30-cps noise out of spec	Open C309, V304 screen bypass
	Weak BT302, V304 bias cell
	Cold solder joints in the AC amplifier
60-cps noise out of spec	Short from signal ground to chassis 1) C301 filter capacitor can to T301 transformer 2) Input shield touching chassis at connector 3) Mounting bolt for "D" circuit board behind attenuator 4) Faulty rubber grommets on subchassis shock mounts
	Open C314, V305 screen bypass
	Open C326, V308 screen bypass
	Defective C301, filter capacitor
	Defective tube, V301 through V305
60-cps oscillation	Defective DC insertion -- faulty C307 or C323 coupling capacitors

Table 4-1. Troubleshooting Guide (Contd)

OPERATING DIFFICULTY	PROBABLE CAUSE
750-cps noise beyond spec (See Figure 4-32c)	Defective chopper
	Defective BT302, V304 bias cell
	Open R423, attenuator resistor
	Defective amplifier tube, V303 through V308
	Poor lead dress
750-cps offset (severe)	Defective chopper
	Defective V304 amplifier
Wideband noise out of spec	Defective capacitor in capacitive deck of attenuator, C401 to C411
	Dirty attenuator switch contacts
on X20 and X30 positions only, in spec otherwise	Open R364, V308 screen-to-ground resistor
	Ground loop
Overload	Open ground lead
	Open R302 voltage divider -- possibly caused by shorted C301B filter capacitor
	Defective C303 filter capacitor
	Open coupling capacitor C305, C310, or C320
	Leaking coupling capacitor C307, C310, or C323
	Leaking C322, V308 plate bypass capacitor
	Shorted C306, V303 plate bypass capacitor
	Shorted C325, V305 coupling capacitor
	Shorted CR303, demodulator diode
	Defective BT301 or BT302, bias cells
	Open R308, V303 plate resistor
	Open R331, V307 cathode resistor
	Defective tubes V305 or V307

Table 4-1. Troubleshooting Guide (Contd)

OPERATING DIFFICULTY	PROBABLE CAUSE
Oscillatory overload -- positive and negative at 1 cps approx (very rhythmic) (See Figure 4-35)	Open C321, V308 coupling capacitor
	Defective V308
Oscillatory overload -- positive and negative but with uneven rhythm of +---, +--, +----	Open chopper
High frequency oscillation	Open bridge bypass capacitors, C316 or C318
	Open C333 output bypass capacitor
Steady oscillation after replacement of chopper or T301 transformer	Reversed polarity between chopper and demodulator
Periodic blown fuse after few moments of operation	Short from CR301/CR302 diode leads to cover plate on left side
	Short from C303 capacitor can to input shield
Shock noise	Defective V303 (microphonic)

lined rather than a small localized core. Similarly, oscillograms are shown to serve as a basis for inspection and comparison of waveforms. Such visual circuit tracing of anomalous waveforms will facilitate the localizing of difficulties.

4-76. The nature of the difficulties guides the troubleshooting diagnosis. Several categories of troubles are discussed below. Specific difficulties are listed together with the circuit flaws in a troubleshooting guide. (Refer to Table 4-1). In all cases, the corrective maintenance required can be expected to be more complex than standard instrument servicing; the troubles will have to be traced by intelligent comparison of voltages and waveforms, deduction, and in many cases, substitution of new parts.

4-77. NOISE. Noise originates in tubes or other faulty components, or may arise from imperfect connections or improper lead dressing. Noise may be a 30- or 60-cps hum or be random in character. If noise is within specifications in the 750-cps band, it is usually within specifications in the 3-cps band. Examples of noisy signals are shown in the oscillograms included in maintenance support data.

4-78. 30-cps noise is usually caused by unbalance between the AC (high frequency) amplifier and the chopper amplifier.

4-79. 60-cps noise may be introduced by poor filters, ground loops, heater-cathode leakage in vacuum tubes, or open screen bypass capacitors.

4-80. Random noise at low frequencies may originate in V303 or V308. High frequency random noise on all gain ranges may be caused by a defective V303. (This tube also is a likely source of microphonic difficulties.) Random wideband noise which begins at a certain gain setting and continues through all consecutive settings is probably caused by an open capacitor in the capacitive deck of the feedback attenuator (C401 through C410). Wideband noise at one single gain setting may arise from an open contact on the switch.

4-81. Persistent random noise is generally caused by improper grounding and/or shielding -- also by cold solder joints. Floating units being serviced out of their cabinets can produce a large masking noise from the disconnected ground strap touching a chassis-grounded lead.

4-82. Improper lead dress is specially conductive to noise, particularly in regard to the input circuit. C305 must lie against the etched board, perpendicular to the chassis and with short leads. C320 also should be flat, parallel to the chassis, and as close to the front of the amplifier as possible. The DC heater lead from V303 and V304 should be as close as possible to the V304 socket and away from the gray- and white ground lead to the attenuator which must be close to the V303 socket. Improper lead dress can increase the noise level by as much as 0.5 microvolt of equivalent input.

4-83. OSCILLATION. High frequency oscillation is probably caused by a defective circuit close to the output -- either the bridge or the feedback attenuator. Amplifiers with short leads and lacking the 500 micromicrofarad bypass across the output may show a tendency to oscillate with some loads; this oscillation may be eliminated by shunt-

ing 500 micromicrofarads from the output to the signal ground.

4-84. Oscillation at a very low frequency -- of the order of 1 cps -- and of an amplitude sufficient to overload the unit is indication of a poor V308 tube or coupling to that tube. An open chopper also causes a type of oscillation but of a characteristically limping period. Refer to Table 4-1.

4-85. OVERLOAD. Overloading can be the result of difference in gains in the AC and DC amplifiers -- such difference produces hum proportional to the unbalance and the hum causes overloading. The gain difference can be caused by partial failure of high voltage, an open input capacitor, or tube failure. Overloads can be caused also by other malfunctions; refer to Table 4-1. Overloads are keyed in oscillograms in maintenance support data.

4-86. OVERLOAD RECOVERY. If the amplifier is within specifications in all matters other than recovery from overload resulting from excessive input signal, trouble is indicated in the DC insertion circuit from the triode plate of V308 to the summing junction at the V304 grid. This condition may be caused by improper bias on the grids of V303B and V308, or failure of one of the circuit parts other than the bias cells.

4-87. DEMODULATOR DIFFICULTIES. Inspection of demodulator waveforms will reveal troubles associated with that circuit readily. (See Figure 4-9.) Distorted waveforms at the demodulator junctions may arise from troubles in the demodulator or from some external source. Short pin 9 of V308 to ground and inspect the waveforms; if they return to normal, the diode circuit is functioning normally and the difficulties must be elsewhere -- if the signals remain distorted, then the trouble is within the demodulator.

4-89 MAINTENANCE SUPPORT DATA

4-90. Tables 4-2 and 4-3 list the voltages and resistances to ground from each pin of each tube socket.

NOTE

The voltage and resistance readings tabulated are subject to mild variations from unit to unit. The readings should be verified with a normally functioning amplifier, and any correction of values should be made.

4-91. Figures 4-26 through 4-35 show oscillograms of waveforms with implicit signal levels to serve as a basis for signal tracing and troubleshooting. Sufficient white space is left besides the oscillograms to augment or correct the waveforms for within-normal deviations of any particular amplifier.

4-92. Table 4-4 lists the replaceable parts in the Model 111 Series Amplifiers. Table 4-5 lists the manufacturers referenced in the parts list.

4-93. Figures 4-36 and 4-37 show the schematic circuit diagrams of the Model 111AF and Model 111BF amplifiers.

Table 4-2. Voltage Readings to Ground

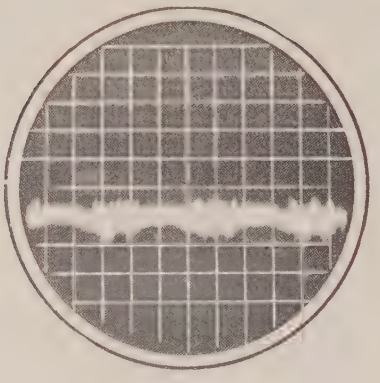
TUBE	Pin Number								
	1	2	3	4	5	6	7	8	9
V301 6X4	AC	NC	FIL	FIL	NC	AC	+410	NP	NP
V302 6X4	AC	NC	FIL	FIL	NC	AC	+200	NP	NP
V303 5751	+125	-1.35	0	0	0	+125	-1.35	0	+5.2
V304 6AU6	-1.35	0	+12	+5.2	+185	+70	0	NP	NP
V305 6CB6	-1.8	0	FIL	FIL	+145	+74	0	NP	NP
V306 6BX7	-12	+135	0	-10	+135	0	FIL	FIL	NP
V307 6BX7	-125	0	-115	-125	0	-115	FIL	FIL	NP
V308 6AW8	0	-1.35	+90	FIL	FIL	0	-1.35	+24	+155

NC INDICATES "No Connection" NP INDICATES "No Pin"

Table 4-3. Resistance Measurements to Ground

TUBE	Pin Number								
	1	2	3	4	5	6	7	8	9
V301	400 Ω	NC	FIL	FIL	NC	400 Ω	80K	NP	NP
V302	130K	NC	FIL	FIL	NC	130K	160K	NP	NP
V303	300K	*	0	0	0	300K	*	0	3 Ω
V304	*	0	4.3 Ω	3 Ω	150K	38K	0	NP	NP
V305	*	0	FIL	FIL	140K	38K	0	NP	NP
V306	170K	160K	0	600K	160K	9K	FIL	FIL	NP
V307	200K	9K	150K	210K	0	150K	FIL	FIL	NP
V308	0	*	300K	FIL	FIL	0	*	3.6M	300K

* Do Not Measure. Bias Cell in Circuit.

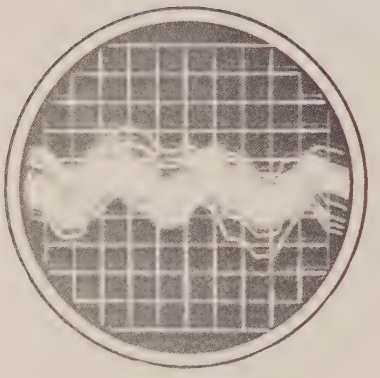


A

A

NORMAL WAVEFORM MEASURED AT PIN 1 OF V303B.

SENSITIVITY: 1 MV PER CENTIMETER.
SWEEP: 5 MILLISECONDS.

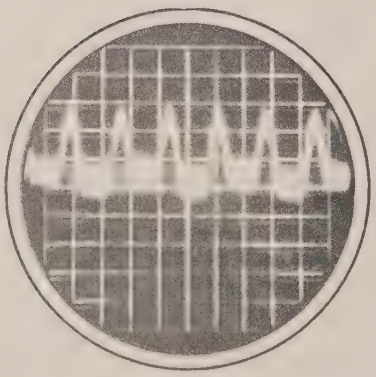


B

B

NORMAL WAVEFORM MEASURED AT PIN 5 OF V304

SENSITIVITY: .05 V PER CENTIMETER.
SWEEP: 5 MILLISECONDS.



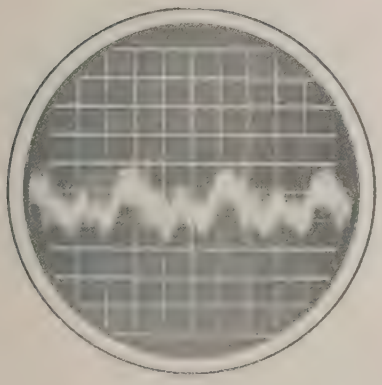
C

C

NORMAL WAVEFORM MEASURED AT PIN 4 OF V306

SENSITIVITY: 10 MV PER CENTIMETER.
SWEEP: 5 MILLISECONDS.

Figure 4-26. Normal Amplifier Waveform



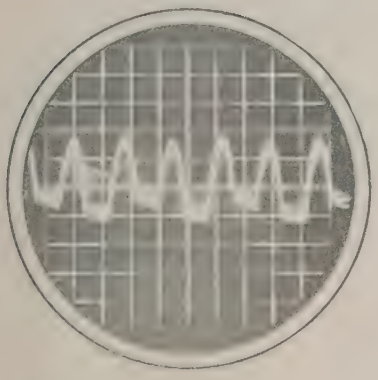
A

A

SENSITIVITY: 2 V PER CENTIMETER.
SWEEP: 5 MILLISECONDS.

NOTE: ERRATIC PATTERN OF THIS WAVEFORM SHOULD BE EXPECTED.

Figure 4-27. Normal Waveform Measured at Pin 9 of V308 (DCA Output)

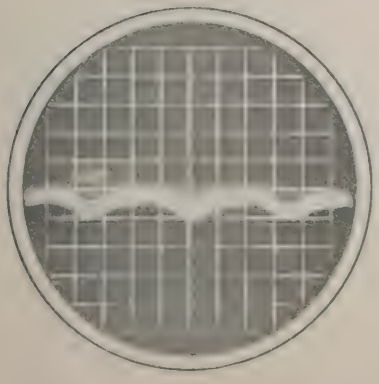


B

B

NORMAL WAVEFORM OF DC FILAMENT-SUPPLY, MEASURED AT C302A.

SENSITIVITY: .5 V PER CENTIMETER.
SWEEP: 5 MILLISECONDS.



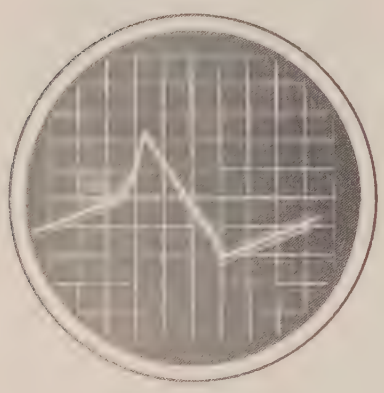
C

C

NORMAL WAVEFORM OF DC FILAMENT-SUPPLY, MEASURED AT C302B.

SENSITIVITY: 0.05 V PER CENTIMETER.
SWEEP: 5 MILLISECONDS.

Figure 4-28. Normal Filament Supply Waveforms

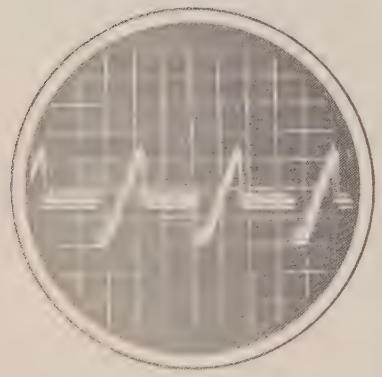


A

A

WAVEFORM SHOWING LOSS OF CHOPPER-DRIVE VOLTAGE.

SENSITIVITY: 10 V PER CENTIMETER.
SWEEP: 0.2 SECOND

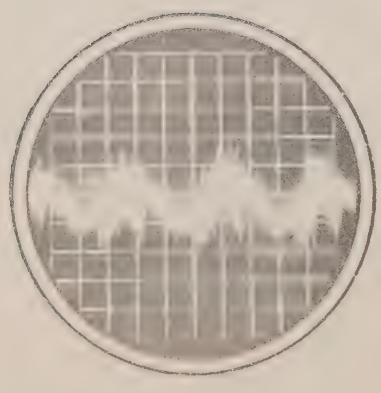


B

B

NORMAL CHOPPER WAVEFORM MEASURED AT PIN 3 OF D301.

SENSITIVITY: 20 MV PER CENTIMETER.
SWEEP: 5 MILLISECONDS.



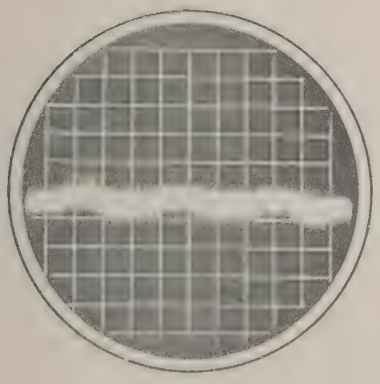
C

C

NORMAL WAVEFORM MEASURED AT PIN 7 OF V308, SHOWING EFFECT OF OPENING AND CLOSING OF CHOPPER CONTACTS. NOTE PERIODIC BURSTS OF NOISE.

SENSITIVITY: 20 MV PER CENTIMETER.
SWEEP: 5 MILLISECONDS.

Figure 4-29. Chopper Waveforms

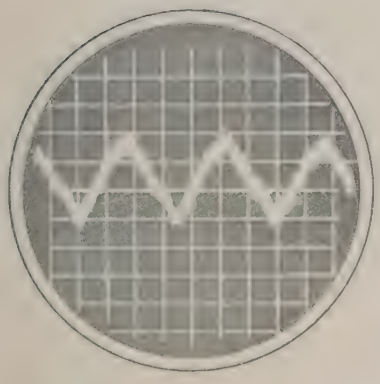


A

A

WAVEFORM SHOWING 750-CYCLE NOISE, MEASURED WITH AMPLIFIER OUT OF ITS MODULE, MAKING NOISE-LEVEL SLIGHTLY HIGHER. SOME 60-CYCLE COMPONENT IS PRESENT.

SENSITIVITY: 20 MV PER CENTIMETER.
SWEEP: 5 MILLISECONDS.

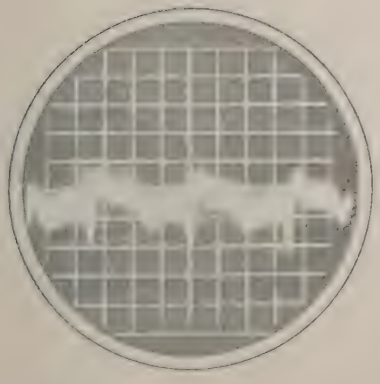


B

B

WAVEFORM SHOWING EXCESSIVE 60-CYCLE COMPONENT, IN 750-CYCLE NOISE TEST.

SENSITIVITY: 20 MV PER CENTIMETER.
SWEEP: 5 MILLISECONDS.



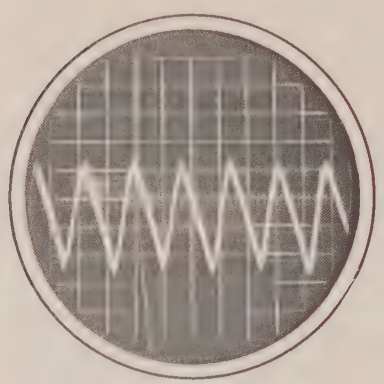
C

C

ABNORMAL VARIATIONS IN 750-CYCLE NOISE. PROBABLE CAUSE: CHOPPER.

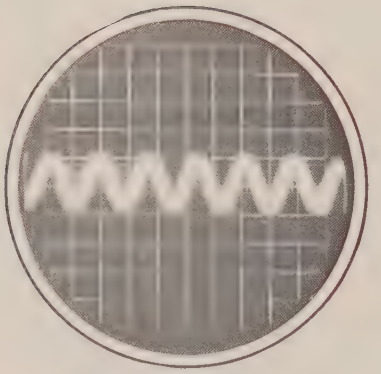
SENSITIVITY: 2 MV PER CENTIMETER.
SWEEP: 5 MILLISECONDS.

Figure 4-30. 750-Cycle Noise



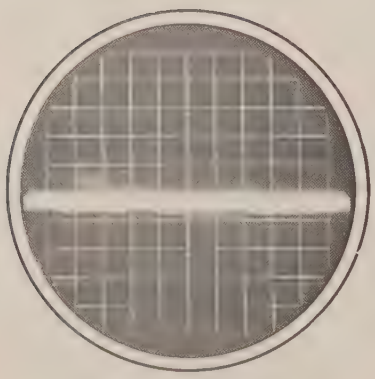
NORMAL RIPPLE MEASURED AT C301A

SENSITIVITY: 1V PER CENTIMETER.
SWEEP: 5 MILLISECONDS.



NORMAL RIPPLE MEASURED AT C301B

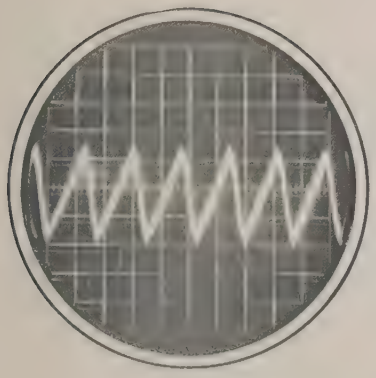
SENSITIVITY: 5 MV PER CENTIMETER.
SWEEP: 5 MILLISECONDS.



NORMAL RIPPLE MEASURED AT C301C

SENSITIVITY: 5 MV PER CENTIMETER.
SWEEP: 5 MILLISECONDS.

Figure 4-31. Normal Ripple at C301

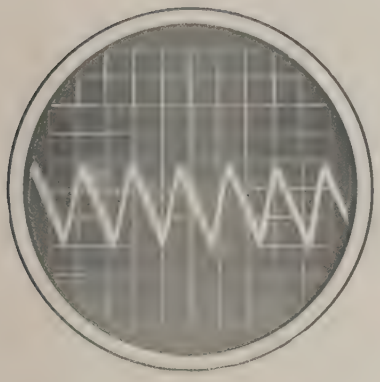


A

A

NORMAL RIPPLE MEASURED AT C303 (NEGATIVE).

SENSITIVITY: 1 V PER CENTIMETER
SWEEP: 5 MILLISECONDS



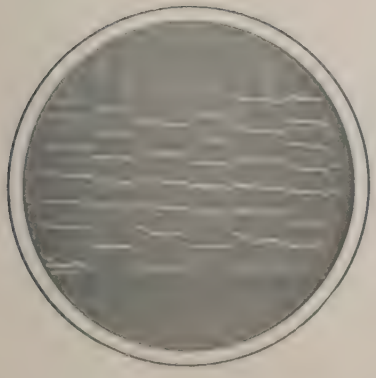
B

B

NORMAL RIPPLE MEASURED AT C303 (POSITIVE).

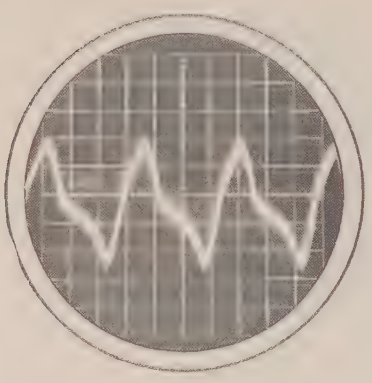
SENSITIVITY: 1 V PER CENTIMETER.
SWEEP: 5 MILLISECONDS.

Figure 4-32. Normal Ripple at C303



SENSITIVITY: 5 V PER CENTIMETER
SWEEP: 5 MILLISECONDS

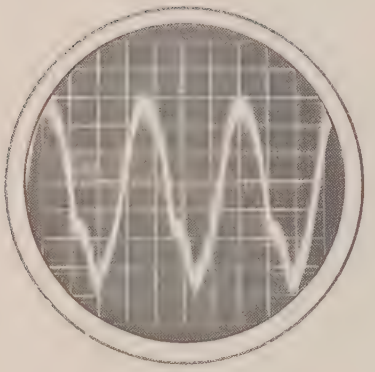
Figure 4-33. Output Signal with Inoperative V308 or Open C321



A

AN ABNORMAL WAVEFORM APPEARING AT POSITIVE JUNCTION OF PHASE-DETECTOR CIRCUIT WHICH MAY OR MAY NOT BE OPERATING IMPROPERLY.

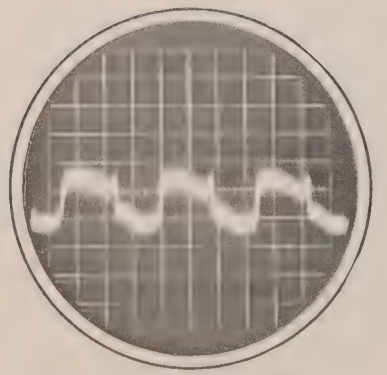
SENSITIVITY: 10 V PER CENTIMETER.
SWEEP: 5 MILLISECONDS.



B

AN ABNORMAL WAVEFORM APPEARING AT NEGATIVE JUNCTION OF PHASE-DETECTOR CIRCUIT WHICH MAY OR MAY NOT BE OPERATING IMPROPERLY.

SENSITIVITY: 5 V PER CENTIMETER.
SWEEP: 5 MILLISECONDS

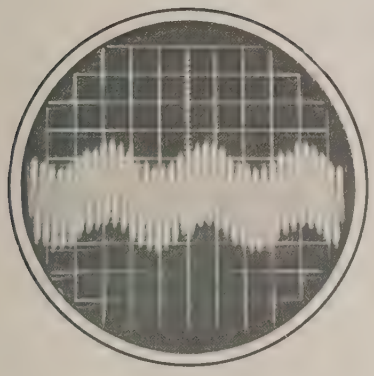


C

AN ABNORMAL WAVEFORM MEASURED AT NEGATIVE JUNCTION OF THE SAME PHASE-DETECTOR CIRCUIT SHOWN IN B BUT IN THIS CASE, WITH PIN 9 OF V308 SHORTED TO GROUND. IF PHASE-DETECTOR CIRCUIT HAD NOT BEEN DEFECTIVE, SHORTING THIS PIN WOULD HAVE PRODUCED A NORMAL WAVEFORM (FIGURE 4-9).

SENSITIVITY: .5 V PER CENTIMETER.
SWEEP: 5 MILLISECONDS.

Figure 4-34. Abnormal Demodulator Waveforms



SENSITIVITY: .5 V PER CENTIMETER
SWEEP: 5 MILLISECONDS.

Figure 4-35. Abnormal Waveform Caused by Microphonic Tube

Table 4-4. List of Replaceable Parts

	CIRCUIT SYMBOL	DESCRIPTION	# MFR	KIN TEL PART NO.
	BT301, 302 303	Bias cell, 1.35V	MAL	1810003-001
	C301A/B/C	Electrolytic can, 20/40/80 µf, 450/450/450V	CD	0510064-003
	C302A/B	Electrolytic can, 1000/1000 µf, 15/15V	CD	0510064-002
	C303A/B/C	Electrolytic can, 20/10/10 µf, 450/450/450V	CD	0510064-004
	C304	Ceramic disc, 50 µµf, 500V	EIA	0401016
B^1	C305	Ceramic tubular, .01 µf, 200V	GAL	0610026-007
B^2	C305	Epoxy-cased mylar, .01 µf, 200V	GAL	0610021-015
A	C306	Ceramic disc, 500 µµf, 500V	EIA	0401039

* - Refer to Table 4-5
A - Used ONLY in Models 111AF and 111AFO
B^1 - Used ONLY in Models 111BF and 111BFO having serial numbers smaller than 2448
B^2 - Used ONLY in Models 111BF and 111BFO having serial numbers 2448 through 4133

Table 4-4. List of Replaceable Parts (Contd)

CIRCUIT SYMBOL		DESCRIPTION	# MFR	KIN TEL PART NO.
B	C306	Ceramic disc, 200 μμf, 500V	EIA	0401027
	C307	Ceramic tubular, .05 μf, 400V	GAL	0610028-011
	C308	Composition, 3 μμf, 500V	STP	0406759-029
	C309	Electrolytic tubular, 8 μf, 150V	MAL	0510002
	C310	Ceramic tubular, .05 μf, 400V	GAL	0610028-011
	C311, 312	Ceramic disc, .01 μf, 500V	EIA	0401056
	C314	Ceramic tubular, .5 μf, 200V	GAL	0610026-017
	C315	Ceramic disc, 500 μμf, 500V	EIA	0401039
	C316, 317 318, 319	Ceramic disc, .01 μf, 500V	EIA	0401056
B[1]	C320	Ceramic tubular, .01 μf, 200V	GAL	0610026-007
B[2]	C320	Epoxy-cased mylar, .01μf, 200V	GAL	0610021-015
	C321, 322	Ceramic disc, .01 μf, 500V	EIA	0401056
A	C323	Ceramic tubular, .1 μf, 200V	GAL	0610026-013
B	C323	Ceramic tubular, .1 μf, 200V	GAL	0610026-007
	C324	Ceramic disc, .01 μf, 500V	EIA	0401056
	C325	Ceramic disc, .02 μf, 500V	EIA	0401058
	C326	Ceramic tubular, .1 μf, 200V	GAL	0610026-013
	C328	Ceramic disc, 50 μμf, 500V	EIA	0401016
	C329	Ceramic disc, .005 μf, 500V	EIA	0401054

\# - Refer to Table 4-5
A - Used ONLY in Models 111AF and 111AFO
B - Used ONLY in Models 111BF and 111BFO
B[1] - Used ONLY in Models 111BF and 111BFO having serial numbers smaller than 2448
B[2] - Used ONLY in Models 111BF and 111BFO having serial numbers 2448 through 4133

Table 4-4. List of Replaceable Parts (Contd)

	CIRCUIT SYMBOL	DESCRIPTION	# MFR	KIN TEL PART NO.
A	C330, 331	Ceramic disc, 100 μμf, 500V	EIA	0401022
B	C331	Ceramic tubular, .1 μf, 400V	GAL	0610028-013
B	C333	Ceramic disc, 500 μμf, 500V	EIA	0401039
B[5]	C334	Electrolytic tubular, 20 μf, 250V	MAL	0501089
	C401	Ceramic disc, 1000 μμf, 500V	EIA	0401046
	C402	Ceramic disc, 2000 μμf, 500V	EIA	0401048
	C403, 404	Ceramic disc, 1000 μμf, 500V	EIA	0401046
	C405	Ceramic disc, 680 μμf, 500V	EIA	0401042
	C406, 407	Ceramic disc, 200 μμf, 500V	EIA	0401027
	C408, 409	Ceramic disc, 100 μμf, 500V	EIA	0401022
	C410	Ceramic disc, 68 μμf, 500V	EIA	0401018
	C411	Ceramic disc, .01 μf, 500V	EIA	0401056
A	C412	Ceramic disc, 500 μμf, 500V	EIA	0401039
B[3]	C412	Molded mica, 100 μμf, 500V	EIA	0703238
	CR301, 302	Diode, Germanium, 1N91	EIA	3506751
	CR303, 304	Diode, Selenium, 3U1	EIA	3506774-007
B	CR305, 306	Diode, Selenium, 3U1	EIA	3506774-007
	D301	Converter, 60-cycle	MIN	6310002
	F301	Fuse, 3AG, 1 Amp, Slo Blo	LTF	1710040-019
	I301	Lamp, pilot, type 47	TSL	1704149

\# - Refer to Table 4-5
A - Used ONLY in Models 111AF and 111AFO
B - Used ONLY in Models 111BF and 111BFO
B[3] - Used ONLY in Models 111BF and 111BFO having serial numbers 2448 and greater
B[5] - Used ONLY in Models 111BF and 111BFO having serial numbers 4134 and greater

Table 4-4. List of Replaceable Parts (Contd)

CIRCUIT SYMBOL		DESCRIPTION	# MFR	KIN TEL PART NO.
	I302	Lamp, neon, type NE 51	DIA	1704152
	I303	Lamp, neon, type NE 2	GCM	1704151
A	I304, 305	Lamp, neon, type NE 2	GCM	1704151
	L301	Choke, 25 μh, .05 ohms	MAL	2306773
	P301	Connector, type DPB-12-34P-2A	KT	1310064
	R301	Wire-wound, 500 ohms, 5W	OHM	5110010-28
	R302	Composition, 10K ohms, 2W	AB	0310032-103
A, B[4]	R303	Composition, 39K ohms, 1W	AB	0310031-393
B[5]	R303	Composition, 56K ohms, 1W	AB	0310031-563
	R304	Wire-wound, 4 ohms, 5W	OHM	5110010-005
	R305	Deposited carbon, 100K ohms, 1/2W, 1%	TEX	4810011-071
	R306	Deposited carbon, 1M ohms, 1/2W, 1%	TEX	4810011-107
	R307	Composition, 10K ohms, 1/2W	AB	0310030-103
	R308	Composition, 220K ohms, 1/2W	AB	0310030-224
	R309, 310	Composition, 330K ohms, 1W	AB	0310031-334
	R311	Composition, 82K ohms, 1W	AB	0310031-823
	R312, 313	Composition, 33K ohms, 1/2W	AB	0310030-333
	R314	Composition, 120K ohms, 1W	AB	0310031-124
	R315	Composition, 27K ohms, 1/2W	AB	0310030-473

\# - Refer to Table 4-5
A - Used ONLY in Models 111AF and 111AFO
B[4] - Used ONLY in Models 111BF and 111BFO having serial numbers smaller than 4134
B[5] - Used ONLY in Models 111BF and 111BFO having serial numbers 4134 and greater

Table 4-4. List of Replaceable Parts (Contd)

	CIRCUIT SYMBOL	DESCRIPTION	# MFR	KIN TEL PART NO.
	R316	Composition, 6.8M ohms, 1/2W	AB	0310030-685
	R317	Composition, 82K ohms, 1W	AB	0310031-823
	R318	Composition, 120K ohm, 1W	AB	0310031-124
	R319	Composition, 47K ohms, 1/2W	AB	0310030-473
	R320, 321	Composition, 1M ohms, 1/2W	AB	0310030-105
	R322	Wire-wound, 2250 ohms, 5W	OHM	5110010-041
	R323	Composition, 680K ohms, 1/2W	AB	0310030-684
	R324, 325	Composition, 100K ohms, 1/2W	AB	0310030-104
	R326	Composition, 120K ohms, 1/2W	AB	0310030-124
	R327	Composition, 100K, 1/2W	AB	0310030-104
	R328	Wire-wound, 2250 ohms, 5W	OHM	5110010-041
	R329	Composition, 82K ohms, 1/2W	AB	0310030-823
	R330	Composition, 680K ohms, 1/2W	AB	0310030-684
	R331	Wire-wound, 1K ohms, 5W	OHM	5110010-034
	R332	Composition, 100K ohms, 1/2W	AB	0310030-104
	R333	Composition, 180K ohms, 1/2W	AB	0310030-184
	R334, 335	Composition, 470 ohms, 1/2W	AB	0310030-471
	R336	Composition, 330K ohms, 1/2W	AB	0310030-334
A	R337	Potentiometer, 10K ohms, 1/2W	CLA	5001865
B	R337	Potentiometer, 10K ohms, 1/2W	AB	5010165
	R338	Composition, 4.7M ohms, 1/2W	AB	0310030-475

\# - Refer to Table 4-5
A - Used ONLY in Models 111AF and 111AFO
B - Used ONLY in Models 111BF and 111BFO

Table 4-4. List of Replaceable Parts (Contd)

	CIRCUIT SYMBOL	DESCRIPTION	# MFR	KIN TEL PART NO.
	R339	Composition, 5.6M ohms, 1/2W	AB	0310030-565
	R340	Composition, 10K ohms, 1/2W	AB	0310030-103
	R341	Composition, 6.8M ohms, 1/2W	AB	0310030-685
	R342	Composition, 22K ohms, 1/2W	AB	0310030-223
	R343	Composition, 680K ohms, 1/2W	AB	0310030-684
	R344	Composition, 1K ohms, 1/2W	AB	0310030-102
	R345, 346	Composition, 10M ohms, 1/2W	AB	0310030-106
	R347	Composition, 220K ohms, 1/2W	AB	0310030-224
	R348	Composition, 3.3M ohms, 1/2W	AB	0310030-335
	R349	Composition, 4.7M ohms, 1/2W	AB	0310030-475
	R350	Composition, 1M ohms, 1/2W	AB	0310030-105
	R351	Composition, 220K ohms, 1/2W	AB	0310030-224
	R352	Composition, 3.3M ohms, 1/2W	AB	0310030-335
A	R353	Composition, 330K ohms, 1/2W	AB	0310030-334
B	R353	Composition, 680K ohms, 1/2W	AB	0310030-684
A	R354	Composition, 4.7 ohms, 1W	AB	0310031-047
	R355	Composition, 2.7M ohms, 1/2W	AB	0310030-275
	R356	Composition, 220K ohms, 1/2W	AB	0310030-224
	R357	Composition, 3.3M ohms, 1/2W	AB	0310030-335
	R358	Composition, 82 ohms, 1/2W	AB	0310030-820

\# - Refer to Table 4-5
A - Used ONLY in Models 111AF and 111AFO
B - Used ONLY in Models 111BF and 111BFO

Table 4-4. List of Replaceable Parts (Contd)

CIRCUIT SYMBOL		DESCRIPTION	# MFR	KIN TEL PART NO.
A	R359	Composition, 1.5M ohms, 1/2W	AB	0310030-155
A	R360	Composition, 4.7M ohms, 1/2W	AB	0310030-475
B	R362	Potentiometer, 10K ohms, 1/2W	CLA	5010157
B	R363	Composition, 1M ohms, 1/2W	AB	0310030-105
B[2]	R364	Composition, 680K ohms, 1/2W	AB	0310030-684
	R402	Composition, 39 ohms, 1/2W.	AB	0310030-390
	R403	Composition, 120 ohms, 1/2W	AB	0310030-121
	R404	Composition, 180 ohms, 1/2W	AB	0310030-181
	R405	Composition, 330 ohms, 1/2W	AB	0310030-331
	R406	Composition, 680 ohms, 1/2W	AB	0310030-681
	R407	Composition, 1.2K ohms, 1/2W	AB	0310030-122
	R408	Composition, 1.8K ohms, 1/2W	AB	0310030-182
	R409	Composition, 2.7K ohms, 1/2W	AB	0310030-272
	R410	Composition, 3.9K ohms, 1/2W	AB	0310030-392
	R411	Composition, 39 ohms, 1/2W	AB	0310030-390
	R412	Wire-wound, 4.5K ohms, 1/2W	CIN	4806796
	R413	Wire-wound, 1.5K ohms, .25%	CIN	4806795
	R414	Wire-wound, 1.2K ohms, .25%	CIN	4806794
	R415	Wire-wound, 514.3 ohms, .25%	CIN	4806791
	R416	Wire-wound, 385.7 ohms, .25%	CIN	4806790

\# - Refer to Table 4-5
A - Used ONLY in Models 111AF and 111AFO
B - Used ONLY in Models 111BF and 111BFO
B[2] - Used ONLY in Models 111BF and 111BFO having serial numbers 2448 through 4133

Table 4-4. List of Replaceable Parts (Contd)

	CIRCUIT SYMBOL	DESCRIPTION	# MFR	KIN TEL PART NO.
	R417	Wire-wound, 4.5K ohms, .25%	CIN	4806796
	R418	Wire-wound, 1.5K ohms, .25%	CIN	4806795
	R419	Wire-wound, 1.2K ohms, .25%	CIN	4806794
	R420	Wire-wound, 514.3 ohms, .25%	CIN	4806791
	R421	Wire-wound, 385.7 ohms, .25%	CIN	4806790
	R422	Wire-wound, 900 ohms, .25%	CIN	4806792
	R423	Wire-wound, 1K ohms, .25%	CIN	4806793
A	R424	Composition, 330K ohms, 1/2W	AB	0310030-334
A	R425	Composition, 1M ohms, 1/2W	AB	0310030-105
	T301	Transformer, Power	TRI	6510004
	V301, 302	Vacuum tube, 6X4	EIA	7002786
	V303	Vacuum tube, 5751(RCA only)	EIA	7302812
	V304	Vacuum tube, 6AU6	EIA	7002748
	V305	Vacuum tube, 6CB6	EIA	7002773
	V306, 307	Vacuum tube, 6BX7GT	EIA	7002768
	V308	Vacuum tube, 6AW8	EIA	7007419

\# - Refer to Table 4-5
A - Used ONLY in Models 111AF and 111AFO

Table 4-5. Manufacturer's Code Designations

CODE	MANUFACTURER	ADDRESS
AB	Allen-Bradley Co.	Milwaukee 4, Wis.
CD	Cornell-Dubilier Elec. Co.	South Plainfield, N. J.
CIN	Cinema Engineering Co.	Burbank, Calif.
CLA	Clarostat Mfg. Co.	Dover, N. H.
DIA	Dialight Corporation	Brooklyn 37, N. Y.
EIA	Any brand meeting EIA standards	
GAL	Good-All Electric Mfg. Co.	Ogallala, Nebr.
GCM	General Cement Mfg. Co.	Rockford, Ill.
KT	Kin Tel	San Diego 12, California
LTF	Littlefuse, Inc.	Des Plaines, Ill.
MAL	P. R. Mallory Co., Inc.	Indianapolis, Ind.
MIN	Minneapolis Honeywell Regulator Co.	San Diego 1, California
OHM	Ohmite Mfg. Co.	Skokie, Ill.
STP	Stackpole Carbon Co.	St. Marys, Pa.
TEX	Texas Instruments, Inc.	Dallas, Texas
TRI	Triad Transformer Corp.	Venice, Calif.
TSL	Tung-Sol Lamp Works, Inc.	Newark 4, N. J.

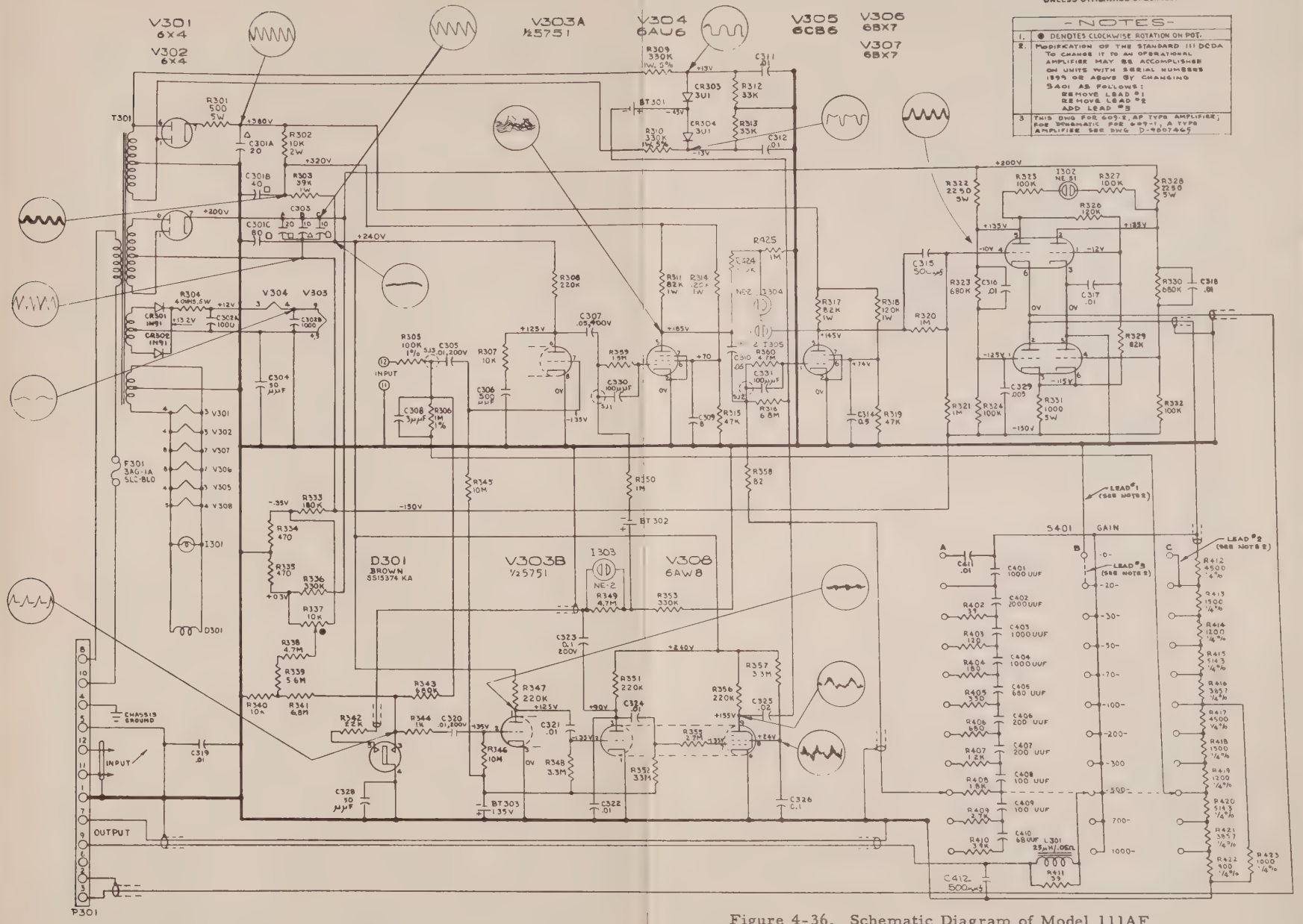


Figure 4-36. Schematic Diagram of Model 111AF Amplifier (Drawing No. D9610091)

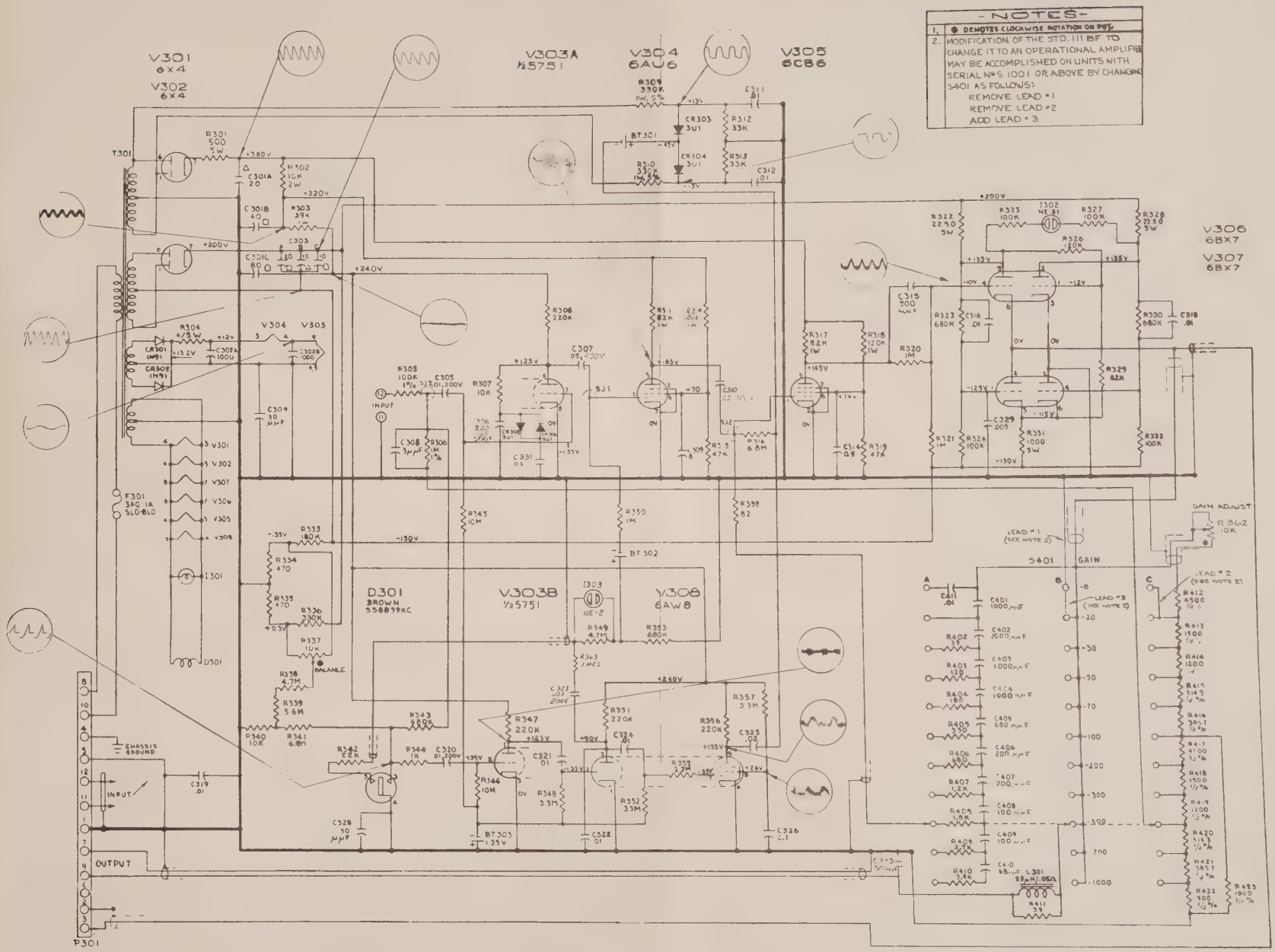


Figure 4-37. Schematic Diagram of Model 111BF Amplifier (Drawing No. 8021100)

INDIVIDUAL INSTRUMENT RECORD AND AUTHORIZATION FOR REPAIR

MODEL NO. _____ SERIAL NO. _____

CUSTOMER P. O. NO. _____

PURCHASED FROM: _____ DATE PURCHASED: _____

SYMPTOMS NOTED: _____

_____

_____

(If application entails environmental or other specific ambient conditions which may affect operation, please describe)*

REPAIR AUTHORIZED BY: (Person, Company and Date)** _____

SPECIFIC REPAIRS REQUESTED: _____

_____

(If additional papers accompany this RECORD, please staple to this sheet. Back of this sheet may be used for further data)

SHIPPING INSTRUCTIONS FOR RETURN OF INSTRUMENT: _____

BALANCE OF THIS FORM TO BE COMPLETED BY REPAIR PERSONNEL ONLY

REPAIR DATE: _____ REPAIR ORDER NO. _____ TECHNICIAN: _____

REPAIRS PERFORMED (Including any discrepancies noted): _____

_____

_____

_____

*If classified information affects repair status, state contact for KIN TEL Security Department.

**Repair must be authorized by KIN TEL or representative personnel and this form returned with instrument.

WARRANTY

WARRANTY: KIN TEL warrants the equipment manufactured by it to be free from defects of material and workmanship under normal use and service. In consideration thereof its obligation and liability under said warranty is limited to servicing or adjusting any instrument returned to its factory for that purpose upon its written instruction, and to make good at its factory any part or parts thereof, except tubes, transistors, fuses and batteries, which shall, within one year (Instruments), or ninety days (Television) after making delivery to the original purchaser, be returned by the original purchaser to KIN TEL with transportation charges prepaid, and which in KIN TEL's examination shall disclose to KIN TEL's satisfaction to have been thus defective. No warranties other than those set forth in this section are given or are to be implied with respect to the equipment furnished hereunder.

For customer convenience, service departments are maintained throughout the United States by KIN TEL field-engineering representatives, where service is available both during and after the warranty period.

KIN TEL
A DIVISION OF
COHU
ELECTRONICS, INC.

5725 Kearny Villa Road San Diego 11, California